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THE INSECTS OF MONA ISLAND (WEST INDIES)

By J. A. Ramos[1]

Introduction

A better and more complete knowledge of the insect fauna of Mona Island has long been desirable from the standpoint of the study of the distribution of insects in the West Indies and of a more thorough knowledge of the entomological fauna of the Puerto Rican region.

The information about [redacted] a Island included in this paper has been obtained [redacted] e first place, the writer has attempted to gather t [redacted] records of insects from Mona Island found in se [redacted] ons and papers dealing mainly with the fauna of I [redacted] to this, a great number of species has been added to those already known from the island and much additional information gathered from a rather extensive collection of insects obtained from the island in April 1935 and during the spring and summer of 1944.

General Information

Location

Mona Island, politically part of Puerto Rico, is located in latitude 18°05′ North and longitude 67°55′ West, in the south side of the Mona Passage between Puerto Rico and Hispaniola. It is approximately 45 miles west-southwest of Mayaguez, Puerto Rico and 40 miles east-southeast of Punta Espada, Dominican Republic. On clear days, both Puerto Rico and Hispaniola are visible from the island. Three miles to the north-northwest lies Monito Island, a very small and inaccessible rock of no particular interest.

Size

The island is roughly circular in shape, with a slight indentation on the north side and an angular outline. It is approximately 6 miles long from

[1] A thesis submitted to the Faculty of the State College of Agriculture and Engineering of the University of North Carolina in partial fulfillment for the Degree of Master of Science in the Department of Zoology and Entomology.

west to east and 5 miles wide from north to south. The total area is about 14,000 acres.

TOPOGRAPHY

The island is relatively flat, with an average elevation of 150 to 175 feet above sea level. The highest elevation is found on the Northwest Cape, which is 272 feet high. The surface consists of two sharply divided levels: the coastal plain and the limestone plateau. The island is surrounded by a coral reef, so complete, that landing a boat is always dangerous, very difficult and almost impossible during certain months of the year.

The coastal plain comprises about 6 per cent of the total land area of the island, or nearly 900 acres. About 90 per cent of it is on the southwestern side (Uvero Beach) where much protection from the wind and surf is afforded. Narrow beaches are also found along the west and south coasts (Sardinera Beach and Playa de Pájaros, respectively), but the north and northeast coasts are cliffs sheer to sea level. The entire coastal plain is low, generally not over 10 feet above sea level. It is several miles long and averages about half a mile wide.

The limestone plateau, nowhere less than 100 feet high, comprises the greatest portion of the area of the island, or more than 13,000 acres. It is bordered nearly throughout by steep escarpments and is accessible at only a few points from the coastal plain. Its surface is sharp and jagged.

The limestone rock is very porous, which permits much subterranean drainage. For this reason, there are no springs or rivers on the plateau despite its relatively large extent. There is, however, some variation in the level of the plateau caused by erosion following rains of heavy intensity. An example of this is Bajura de los Cerezos, a sink-hole near the center of the island, where subterranean drainage is exceptionally high, and where the washed-in soil permits a richer and more abundant vegetation.

A striking character of Mona Island is the fact that it is honeycombed with numerous caves and caverns, some of considerable size. Centuries of water seepage through the soluble limestone have been responsible for their development. They may be seen in the cliffs at any part of the island and a few open out on the surface of the plateau. These caves were once an important source of guano which was commercially removed from them many years ago.

CLIMATE

The climate of Mona Island seems to be very similar to that of Guánica, on the south coast of Puerto Rico, judging from the scanty available information. Daily temperatures are high and the precipitation rather low. A

rain gauge maintained for the last 22 years at the Lighthouse of East Cape has received an average annual rainfall of 40.66 inches.

SOIL

The parent rock is Ponce limestone (Miocene). It gives rise to a soil very similar to shallow phase Ensenada clay. This reddish, pliable and very shallow soil is very sparse and found only in depressions on the surface of the plateau. Its depth varies from 0 to possibly 2 feet in some of the largest depressions.

On the coastal plain, the soil is deeper and more abundant than on the plateau. It consists chiefly of consolidated beach material containing coral and shell fragments.

VEGETATION

Despite the arid climate and the paucity of the soil, the plateau is almost completely covered with an open forest of shrubs and low trees of a considerable number of species. Several species of cacti also inhabit it and show abundant growth at some places. The snowy cactus, *Neomammillaria nivosa* (Link) Britton & Rose, a species which does not occur in Puerto Rico, is plentiful. *Cephalocereus Royeni* (L.) Britton & Rose, several species of *Opuntia* and *Cactus intortus* Mill. are also common. Tall grasses are found on some places, but generally the herbaceous vegetation is not abundant on this level. The browsing of the several thousand wild goats and pigs has undoubtedly influenced to some extent the character of the vegetation of the plateau.

On the coastal plain, probably due to the deeper and more abundant soil and to the moister condition, several species of trees reach a larger size and form a denser and higher forest. The herbaceous vegetation is also richer than on the upper level. This richer vegetation may be also observed, however, on some of the larger depressions on the plateau, where, for the same reasons, a denser forest occurs. An example of this is Bajura de los Cerezos.

On the western and southwestern coastal plains, from Sardinera Beach to Uvero Beach, the vegetation has been modified by cutting and clearing for agriculture and reforestation purposes. The Insular Forestry Service planted, from 1937 to 1939, 420 acres in this region to Australian pines, *Casuarina equisitifolia* Forst.; Dominican mahogany, *Swietenia Mahagoni* (L) Jacq.; and "avelluelo", *Colubrina colubrina* (Jacq.) Millsp. The Australian pine has been very successful on this sandy soil, but the "avelluelo" has failed, especially near the coastline, possibly because the salinity of the soil. The success of the mahogany, which was planted on shallow rocky sites, seems not to be too good either.

Britton 1915: 36 gives a total of 230 species of flowering plants from the island, of which only 2 are endemic. These are a small tree, *Tabebuia lucida* Britton, rather common on the plateau, and *Chamaesyce monensis* Millsp., a small plant occurring also on that situation.

Some of the most common species of plants on the island (Britton 1915: 37–49) are the following: *Ficus Stahlii* Warb., *Coccolobis uvifera* (L.) Jacq., *Coccolobis laurifolia* Jacq., *Pisonia albida* (Heimerl) Britton, *Sesuvium Portulacastrum* L., *Capparis cynophallophora* L., *Capparis flexuosa* L., *Pithecolobium Unguis-cati* (L.) Mart., *Cracca cinerae* (L.) Morong, *Guaiacum sanctum* L., *Guaiacum officinale* L., *Amyris elemifera* L., *Elaphrium Simaruba* (L.) Rose, *Stigmaphyllon lingulatum* (Poir.) Small, *Metopium toxiferum* (L.) Krug & Urban, *Corchorus hirsutus* L. *Gossypium barbadense* L., *Clusia rosea* Jacq., *Canella Winteriana* (L.) Gaertn., *Carica Papaya* L., *Cephalocereus Royeni* (L.) Britton & Rose, *Opuntia Dillenii* (Ker-Gawl.) Haw., *Eugenia buxifolia* (Sw.) Willd., *Plumiera obtusa* L., *Lantana Camara* L., *Tabebuia lucida* Britton, *Guettarda elliptica* Sw., *Pluchea purpurascens* (Sw.) DC., and *Aklema petiolare* (Sims) Millsp.

FAUNA

Although the land fauna of Mona Island is not very rich in number of species, it is however very interesting, and, for this reason, has received much attention from several students of the Puerto Rican fauna.

Amphibians and Reptiles

Schmidt 1928: 8 reports 9 species of amphibians and reptiles from the island of which 6 species are endemic to it. These are a small frog, *Eleutherodactylus monensis* Meerw.; the rock iguana, *Cyclura stejnegeri* Barb. and Noble, probably the most conspicuous and interesting feature of the fauna of the island; a small iguana, *Ameiva alboguttata* Boul.; and three snakes: *Typhlops monensis* Schmidt, *Epicrates monensis* Zenneck, and *Alsophis variegatus* Schmidt.

Birds

Wetmore 1927: 245–598 records 22 species of birds from the island. Of these, the most interesting form is a ground-dove, *Columbigallina passerina exigua* Riley, which occurs only on Mona and on the island of Inagua, in the southern Bahama Islands, the rest being common species in other West Indian islands. Danforth 1936: 100 adds 4 species to Wetmore's list. These are two North American migrants, the ani, and the Hispaniolan race of the sparrow hawk, *Falco sparverius dominicensis* Gmelin.

Mammals

Two species of bats which are widely distributed throughout the Greater Antilles and the Virgin Islands, *Noctilio vespertinus mastivus* Dahl and *Mormoops blainvillii* Leach, are the only mammals known from Mona Island (Anthony 1926: 208). They are not common and are found in the numerous caves that occur all over the island.

Wild goats and pigs are abundant on the plateau and together with the large number of scaled and white-headed pigeons present during certain months of the year, constitute an important attraction for sportsmen and hunters from Puerto Rico.

AGRICULTURE

Because of the scant rainfall, poor soil, and great distance from markets, agriculture has never proven practical on Mona Island. A small area on the southwestern coastal plain was once cultivated and it is said that cotton, papayas, and watermelons were successfully produced. Pasturing has been more feasible but has been done only to the extent needed by the few to whom the island was leased in the past.

HISTORICAL RÉSUMÉ

The earliest published records of insects from Mona Island appear to be those of the elaterid *Adelocera rubida* Schwarz and of the phasmid *Lamponius bocki* Brunner and Redtenbacher, described from the island in 1902 and 1908 respectively. Since a German concern was engaged for several years, from the end of the last century to the beginning of the present one, in removing guano from Mona Island, it appears probable that the material from which these two species were described was secured by somebody in the German personnel of that concern, who sent it to museums in his homeland.

Mr. E. G. Smyth and Mr. R. H. Van Zwaluwenburg appear to have been the first entomologists to visit the island and collect insects there, going by sailboat from Mayagüez in December 1913. The few records of insects collected by Smyth at that time on Mona are listed in the accession catalogue of the Agricultural Experiment Station of the University of Puerto Rico at Río Piedras under the numbers 1300 to 1399 in 1913.

Until 1914 when the explorations for the Scientific Survey of Puerto Rico and Virgin Islands, under the combined auspices of the New York Academy of Sciences, the American Museum of Natural History, and the University of Puerto Rico, were initiated, Mona Island was practically unknown and unexplored entomologically. During February 21–26 of that year, a small party of scientists visited the island for the purpose of exploring it

and collecting plants and animals. Dr. Frank E. Lutz, of the American Museum of Natural History, was among the members of that party. During the 5 days he spent on the island he collected rather intensively, contributing much to our present knowledge of the insect fauna of Mona. Many of the new species of insects that have been described from the island have been from the material secured by him on that occasion.

In April 1935 the writer accompanied the late Dr. Stuart T. Danforth on a 3-day trip to Mona Island, primarily for the purpose of studying and collecting birds. A small collection of insects made by him on that occasion is reported in this paper for the first time.

Mr. Francisco Sein Jr. was on Mona Island in August 1926, and Dr. George N. Wolcott visited it by airplane on January 24, 1940, to advise regarding an extensive outbreak of thrips on onions being grown on the coastal plain.

Dr. Luis F. Mortorell, now an entomologist of the Agricultural Experiment Station of the University of Puerto Rico, obtained determinations of insects collected on Mona in March 1937, by Mr. M. A. Perez of the Insular Forestry Service. On August 4–7, 1939 and March 29–April 4, 1940, he collected rather intensively there, adding much information about the insects of the island. He is responsible for many of the records from Mona in the accession catalogue of the Agricultural Experiment Station of the University of Puerto Rico for the years 1939 and 1940 as reported by Wolcott 1941: 33-158.

Professor Virgilio Biaggi, Jr., of the Biology Department, College of Agriculture and Mechanic Arts of the University of Puerto Rico, was on an expedition from the Institute of Tropical Agriculture of Mayaguez, Puerto Rico, that visited Mona Island during March 2–7, 1944 for the purpose of collecting plants and animals. Although he was primarily engaged in collecting specimens of birds, reptiles and amphibians, Professor Biaggi was able to make a small collection of insects for the writer during his visit.

On April 1–7, 1944 Dr. George N. Wolcott, Dr. Luis F. Martorell, and Mr. Jorge Serralés, of the Agricultural Experiment Station of the University of Puerto Rico, and the writer visited the island and collected intensively along the western and southwestern coastal plains and on several places on the plateau.

During the summer of the same year, several persons visited Mona and kindly collected insects for the writer, thus adding many species new to his Mona Island collection and much additional data about the island's entomological fauna. They are Messrs. Enrique Huyke and Antonio Ferrer Monge of Mayaguez, Puerto Rico, who spent several days on the island during the latter part of June and July respectively, and Mr. Harry A. Beatty of St. Croix, Virgin Islands, who stayed on the island from August

11 to August 31 and who collected at Sardinera and Uvero Beaches and all over the plateau.

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Professor Virgilio Biaggi, Jr. College of Agriculture and Mechanic Arts of the University of Puerto Rico; Mr. Harry A. Beatty, of St. Croix, V. I.; Mr. Enrique Huyke and Mr. Antonio Ferrer Monge, of Mayaguez, P. R., assisted in collecting some of the material.

Mr. Luis A. Izquierdo, Commissioner of Agriculture and Commerce of Puerto Rico, kindly furnished the writer with information on the climate, topography, soil, etc., and a map of Mona Island.

The writer is much obliged to all these persons and he wishes to express to everyone of them his deepest gratefulness and indebtedness for their generous cooperation.

SYSTEMATIC ACCOUNT OF THE INSECTS

Order THYSANURA

Family LEPISMATIDAE

Five specimens of an undetermined lepismatid were taken under dead leaves near the cliff at Sardinera Beach, August 11–31, 1944.

Order Collembola

Family entomobryidae

Lepidocyrtinus sp.

Det. Grace E. Glance

Numerous specimens collected under stones, near Sardinera Beach, March 6, 1944.

Order Orthoptera

Dr. B. B. Fulton, Department of Zoology and Entomology, North Carolina State College of Agriculture and Engineering, kindly determined or confirmed the writer's determinations of the Orthoptera obtained from Mona Island.

Family blattidae

Aglaopteryx devia Rehn

Reported from Mona Island by Rehn and Hebard 1927: 7–8 as *A. diaphana* Fabricius, which, according to Guerney 1937: 104, is a Cuban species that does not occur in the Puerto Rican region.

Blattella germanica Linnaeus

Wolcott 1941: 49 reports this species as a pest in houses, August 5, 1939 and March 30, 1940. Not observed by the writer during his trip to the island in April 2–7, 1944.

Symploce flagellata Hebard

Described by Hebard 1916: 367 from Desecheo and Mona Islands. Two of the paratypes were collected on Mona by F. E. Lutz on February 21 and 24, 1914. Rehn and Hebard 1927: 136 remark that this species "does not occur in the island of Puerto Rico itself".

Symploce bicolor Palisot de Beauvois

In houses, Sardinera Beach, March 29, 1940 (Wolcott 1941: 39).

Symploce bilabiata R. & H.

Determined A. B. Gurney.

Collected by Harry A. Beatty, Aug. 21, 1944

Pelmatosilpha coriacea Rehn

First recorded from Mona Island by Rehn and Hebard 1927: 149, who mention a male specimen taken on the island on February 24, 1914 by F. E. Lutz. Wolcott 1941: 40 records specimens taken under guava leaves and under the bark of a dead tree at Sardinera Beach, August 6, 1939.

The writer collected one specimen in the same locality under the bark of a dead tree, April 4, 1944. He also has specimens taken at Uvero Beach on August 11–31, 1944.

Periplaneta americana Linnaeus

The writer has specimens taken in houses at Sardinera Beach, August 11–31, 1944, when the species was found rather abundant.

Periplaneta australasiae Fabricius

This species was found common in houses at Sardinera Beach on August 11–31, 1944.

Epilampra mona Rehn and Hebard

Rehn and Hebard 1927: 216–218 described this species from a single female specimen collected on *Tillandsia utriculata* L. at Sardinera Beach on February 24, 1914 by F. E. Lutz. The writer collected one specimen under the bark of a dead tree at the same locality on April 4, 1944.

Pycnoscelus surinamensis Linnaeus

Rehn and Hebard 1927: 245 report specimens taken under wood at Sardinera Beach on February 21–26 by F. E. Lutz. Wolcott 1941: 32 records specimens under stones at Camp Cofresí, August 7, 1939. The writer has two specimens from Uvero Beach, August 11–31, 1944.

Family MANTIDAE

Callimantis antillarum Saussure

Wolcott 1941: 40 gives 3 records for this species from the island (Acc. Nos. 14–37; 53–40 and 252–40). The writer collected numerous nymphs and adults at Sardinera Beach and Uvero Beach by sweeping over shrubbery and weeds, April 4–6, 1944. He has other specimens taken July 20 and August 11–31, 1944.

Family PHASMIDAE

Lampomius bocki Brunner and Redtenbacher

Described from Mona by Brunner and Redtenbacher 1908: 357.

Aplopus sp.

Reported by Wolcott 1941: 40 (Acc. No. 16–37).

Family TETTIGIDAE

Paratettix frey-gessneri Bolivar

Numerous specimens were taken by the writer at Uvero Beach, April 1935.

Family LOCUSTIDAE (ACRYDIIDAE)

Sphingonotus haitiensis Saussure

Wolcott 1941: 40 reports numerous specimens from grass and weeds at the airport and Playa de Pájaros, August 9, 1939. The writer has specimens swept from vegetation at Sardinera and Uvero, April 5 and August 11–31, 1944.

Scyllina (Plectrotettix) gregarius Saussure

Reported by Wolcott 1936: 37 (Acc. No. 1318–13). The writer has specimens taken on weeds at Sardinera, Uvero and the plateau, April 4 and August 11–31, 1944.

Schistocerca americana Drury

Wolcott 1936: 37 reports this species for the first time from Mona (Acc. No. 1315–13). Later (1941: 40) he records it as abundant at Sardinera and on the plateau, feeding on grasses and trees, August 6, 1939 and March 30, 1940. The writer collected a nymph by sweeping over shrubs on the plateau, April 5, 1944.

Schistocerca columbina Thumberg

The only record of this species from the island is that given by Wolcott 1936: 37 (Acc. No. 1316–13).

Family TETTIGONIIDAE

Microcentrum triangulatum Brunner

Wolcott 1941: 40 records specimens taken at light at Sardinera Beach, August 8, 1939 and at the Lighthouse, April 1, 1940. The writer has specimens collected also at light at Sardinera Beach on March 3, July 22, and August 11–31, 1944.

Neoconocephalus triops Linnaeus

Two specimens taken on the plateau, August 11–31, 1944.

Conocephalus cinereus Thunberg

The writer collected numerous nymphs and adults on grass along the beach at Sardinera, April 4, 1944. He has other specimens from the same locality dated August 11–31, 1944.

Family GRYLLIDAE

Cycloptilum antillarum Redtenbacher

Numerous specimens were swept from vegetation at Sardinera and Uvero Beaches, April 1935, March 2 and August 11–31, 1944.

Cycloptilum sp.

Several specimens taken at Uvero Beach by sweeping on vegetation, April 4, July 21, and August 11–31, 1944.

Gryllus assimilis Fabricius

Uvero Beach, April 1935 and Sardinera Beach, August 11–31, 1944.

Cyrtoxipha gundlachi Saussure

Several specimens were swept from shrubbery at Uvero Beach, August 11-31, 1944.

Orocharis vaginalis Saussure

Several nymphs were swept from weeds at Uvero Beach on June 29, 1944. An adult was taken at Sardinera, August 11-31, 1944.

Oecanthus niveus De Geer

One specimen swept from shrubs, Sardinera Beach, June 29, 1944. Others at Uvero, August 11-31, 1944.

Amphiacusta caraibea Saussure

Wolcott 1941: 41 reports this cricket common in caves and houses, August 5-8, 1939. The writer noticed it very common in houses and under objects on the ground at Sardinera and Uvero Beaches, April 3–7, 1944. Specimens were taken on June 29, July 21, and August 11–31, 1944.

Family TRIDACTYLIDAE

Ellipes minuta Scudder

The writer collected one specimen at light, Sardinera Beach, April 7, 1944.

Order Dermaptera

Family LABIDURIDAE

Labidura riparia Pallas

Wolcott 1941 : 39 reports this species at light at the Lighthouse, April 1, 1940.

Order Isoptera

The determinations of all the species of termites from Mona Island in the writer's collection were made by Professor Alfred Emerson, Department of Zoology, Chicago University, whose comments on the species are here included with his kind permission.

Family KALOTERMITIDAE

Kalotermes mona Banks

Banks 1919: 478 described this species from Mona Island from soldiers taken there on February 21, 1914.

Several soldiers and nymphs and a single dealate were collected by the writer on a dead branch of a living tree of *Melicocca bijuga* L. at Uvero Beach, April 5, 1944. Martorell also secured soldiers and a single alate on the same occasion. The writer's specimens were compared by Professor Emerson to a paratype in his collection and made topotypes by him. His determination is accompanied by the following remarks: "The collections mentioned above are all that are known of this species. So far no record has been obtained from any other locality than Mona Island. The species is quite distinct from all other described species, possibly being closer to *K. jouteli* Banks than to any other species. The imago caste has not been described."

Kalotermes snyderi Light

Wolcott 1941: 41 reports this species in "sanguinaria" tree, August 8, 1939. Martorell recorded it attacking the following trees: *Dipholis salicifolia*, *Metopium toxiferum*, *Elaphrium Simaruba*, *Amyris elemifera*, *Coccolobis uvifera*, *Canella Winteriana*, *Pithecollobium Unguis-cati* and *Gymanthes lucida* on April 1, 1940 (Acc. No. 296-40). Wolcott noted the species, April 5, 1944, on *Coccolobis laurifolia*, *Coccolobis uvifera*, *Conocarpus erecta*, *Rawolfia nitida* and *Metopium toxiferum* (Acc. No. 45-44).

Kalotermes incisus Silvestri

One soldier taken on July 21 and alates, soldiers and nymphs on August 11-31, 1944.

In giving his determination, Professor Emerson states: "I am not completely confident of the determination of this species. Silvestri described *K. incisus* from St. Jean, Venezuela, in 1903. The type is supposed to be in Copenhagen and has not been redescribed. The original description is not exact enough to be sure of the identity of the specimens before me. I have a fair number of alates and soldiers which are the same as the Mona Island specimens from St. Croix and Barbados. I have named these specimens *K. incisus* with some doubt. I also have a single alate from Caracas, Venezuela, which has a slightly smaller eye and may be a different species. I am thus unable to make accurate determinations until the type specimen has been examined or further collections have been made near the type locality".

Procryptotermes corniceps Snyder

Alates, one soldier, and nymphs, March 1; alates at light, Sardinera

Beach, April 7 and June 29; alates and nymphs from an old stump, Uvero Beach, August 11–31, 1944.

Professor Emerson's determination of this species is accompanied by the following remarks: "This species was described by Snyder in 1923 from 2 dealates and 2 soldiers from Boqueron-Salinas, Porto Rico. No further material has been collected since that time. I have one dealate and one soldier paratype in my collection with which I compared your specimens. The cotype soldier has a sharper ridge between the vertex and front which I assume to be within the expected variation but more extensive collections must be made before the significance of this variation can be determined. Snyder placed the species originally in *Glyptotermes* and later (1925) placed it in *Calcaritermes*. I have no hesitation in placing it in the genus *Procryptotermes* on the basis of both soldier and alate characters. The wings, which Snyder did not see, are of the *Cryptotermes* and *Procryptotermes* type and definitely different from the *Glyptotermes* and *Calcaritermes* type. The dentation of the imago mandible is also of the *Cryptotermes* and *Procryptotermes* type. The soldier is a more generalized type than found in *Cryptotermes*. The genus *Procryptotermes* was originally described from species from Madagascar and Aldabra. However, I have been determining both old species and new species as *Procryptotermes* for several years from various parts of the world including a number of New World species. One species very closely related to *P. corniceps* is found in Jamaica, but has not yet been described."

Order NEUROPTERA

Mr. Nathan Banks, Museum of Comparative Zoology, Harvard College, kindly determined all the specimens of Neuroptera from Mona Island in the author's collection.

Family CHRYSOPIDAE

Chrysopa thoracica Walker

This seems to be the most common chrysopid in the island. Martorell collected one specimen on the plateau, March 29, 1940 (Acc. No. 287–40), and the writer found it very abundantly at light at Sardinera Beach on April 7, 1944. Numerous specimens were also taken at light on June 29 and July 22 at Sardinera Beach.

Chrysopa transversa Walker

This species is known only from 2 specimens collected at light at Sardinera Beach on April 7, 1944.

Chrysopa damiensis Smith

A single specimen of this species was collected at light, Sardinera Beach, March 4, 1944.

Nodita haitiensis Smith

A specimen of this species collected on the island on April 1935, and determined by Mr. Nathan Banks, is deposited in the collection of the College of Agriculture at Mayaguez, Puerto Rico.

Family MYRMELEONIDAE

Psammoleon bistictus Hagen

Wolcott 1941: 47 reports this antlion common at light at Sardinera Beach on August 5–6, 1939 and April 1, 1940.

Psammoleon minora Banks

There are four specimens of this species in the author's collection labeled Sardinera Beach, July 29, 1944.

Myrmeleon insertus Hagen

The writer found this species rather common at light at Sardinera Beach on April 4–7, 1944. Numerous larvae, presumably of this species, were also found in loose dry sand in many places at the same locality.

Family ASCALAPHIDAE

Ululodes opposita Banks

Martorell collected specimens of this beautiful ascalaphid at Sardinera Beach on August 6, 1939 (Wolcott 1941: 48). The species is represented in the writer's collection by two specimens swept from shrubbery at Uvero Beach, August 11–31, 1944.

Order ODONATA

Family LIBELLULIDAE

Orthemis ferruginea Fabricius

Klots 1932: 7 records this species from Mona Island without date. Wolcott 1941: 47 reports the species common at Sardinera, March 30, 1940.

Erythrodiplax umbrata Linnaeus

Wolcott 1941: 47 reports specimens taken at Sardinera on August 6, 1939 and April 1, 1940.

Tramea abdominalis Rambur

Recorded from the island by Klots 1932: 7 without definite locality or date.

Lepthemis vesiculosa Fabricius

Several specimens observed at Sardinera on April 4–7, and August 11–31, 1944, but none collected.

Family COENAGRIONIDAE

Enallagna civille Hagen

Reported by Wolcott 1941: 47 from Sardinera, April 1, 1940.

Order MALLOPHAGA

Family PHILOPTERIDAE

Esthiopterum gracilicornis major Kellog

Wolcott 1941: 46 reports this species from man-o'-war bird, *Fregata magnificens rothschildi* Mathews (Acc. No. 388–39).

Order THYSANOPTERA

Family THRIPIDAE

Thrips tabaci Lindeman

This important and injurious species, commonly known as the onion thrips, is the only member of the order Thysanoptera so far recorded from Mona Island. Wolcott 1941: 49 reports it attacking onions planted at Camp Cofresí (Acc. No. 29–40) in 1940.

Order HOMOPTERA

Family MEMBRACIDAE

Paradarnoides danforthi, n. sp. Figs. 1, 2, 3, and 4.

Head very broad and short, nearly concealed from above by pronotum, rugose, covered with abundant golden pubescence, fuscous, becoming paler on upper margin, lateral border at base of eyes, apical portion of post-clypeus, and outer margin of lorae; eyes large and prominent, testaceous, with a reddish rim near base; ocelli conspicuous, widely separated, closer to eyes than to each other, testaceous, flat in front; antennae placed in a large cavity directly below ocelli, testaceous, flagellum infuscated at base. Pronotum testaceous, rather closely and evenly ferrugineous-punctate, sides of metopidium, directly behind eyes, depressed, each with a large fuscous, rugged patch; median carina conspicuous throughout its entire length and decidedly more elevated on posterior process; lateral carinae running from shoulders to apex of posterior process, also conspicuously raised; shoulders set far back from eyes, obtusely prominent, width across them equal to that of head; posterior process gradually narrowed from shoulders to apex, with a slight sinuation near middle, tip distinctly surpassing abdomen. Tegmina hyaline, with base brownish and punctured, veins brown, outer ones with short, curved hairs. Underside fuscous, pubescent. Abdomen light yellow, tip infuscated; legs testa-

ceous, densely clothed with whitish long pubescence; anterior and middle femora and tibiae somewhat infuscated on anterior surface, tarsi fuscous.

Length including tegmina, 4.67 mm.; width across shoulders, 2.0 mm.

Type, male, Mona Island, June 29, 1944.

The genus *Paradarnoides* Fowler includes two other species, *severini* Fowler and *ignipes* Fowler, described from Guadeloupe in the Lesser Antilles (Fowler 1894: 423). The Mona Island species differs from these in its smaller size and different color.

The writer takes great pleasure in dedicating this species to the late Dr. Stuart T. Danforth, who was his close friend and constant teacher for many years.

Family BYTHOSCOPIDAE

Agallia albidula Uhler

Reported by Wolcott 1941: 50 on weeds at Sardinera, March 30, 1940. The writer has specimens swept from weeds at Sardinera Beach, April 4 and from *Pluchea purpurascens* at Uvero, April 5, 1944.

Family CICADELLIDAE

Hortensia similis Walker

A single specimen taken at light, Sardinera Beach, March 3, 1944.

Poeciloscarta histrio Fabricius

Wolcott 1941: 51 reports this species on castor bean at Rancho Grande, August 8, 1939, and abundant on grasses and at light (as *Cicadella sirena* Stål, a Mexican species), Sardinera Beach, March 30, 1940. The writer has specimens swept from weeds at Sardinera, March 1, and July 19, 1944.

Family JASSIDAE

Platymetopius loricatus Van Duzee

Specimens swept from shrubbery at Uvero, April 7, 1944.

Deltocephalus maculellus Osborn

One specimen swept from weeds, Uvero Beach, March 3, 1944.

Thamnotettix colonus Uhler

Specimens swept from weeds, Uvero Beach, March 3, 1944.

Thamnotettix cubanus Ball

A single specimen taken on weeds, Uvero Beach, March 3, 1944.

Chlorotettix tethys Van Duzee

Three specimens taken at light, Sardinera Beach, April 4–5, 1944.

Nesosteles guajanae DeLong

Specimens swept from weeds at Sardinera Beach, March 3, 1944.

Family EUPTERYGIDAE

Hybla maculata McAtee

Wolcott 1941: 53 reports this species abundant under the leaves of an unspecified plant at Sardinera Beach, March 31, 1940.

Family CIXIIDAE

Oliarus franciscanus Stål

Reported by Wolcott 1941: 53 (as *O. complectus* Ball) on weeds at Sardinera Beach, March 30, 1940. The writer collected a single specimen by sweeping on weeds at Uvero, April 4, 1944.

Family ARAEOPIDAE

Liburnia furcifera Horváth

A single specimen taken at light, Sardinera Beach, March 3, 1944.

Family KINNARIDAE

Paraprosoptropis, n. gen. Figs. 5, 6, 7, 8, and 9.

Head, across eyes, about three-fifths width of pronotum. Vertex a little longer than wide, expanding basad; base about one and a half times width of vertex at narrowest point, angularly emarginate, with a conspicuous marginal carina; median and lateral carinae well-developed, running down to apex of frons. Frons almost one and a half times longer than wide, base about half as wide as apex, sides gradually expanding for about four-fifths from base, then slightly converging towards apical margin, which is nearly straight; median and lateral carinae prominent. Clypeus about as wide as long, base slightly but distinctly narrower than frons at widest part, sides converging acutely to apex; median carina very prominent, somewhat wider than that of frons, lateral carinae also well developed; surface slightly concave. Antennae with basal segment very short, second segment stout, decidedly longer than broad; flagellum about $3\frac{1}{2}$ times longer than second segment. Eyes deeply emarginate ventrally above antenna. Pronotum one and a half times longer than vertex, anterior margin sinuate behind eyes, then smoothly curving posteriorly, posterior border nearly straight, curving anteriorly at sides; tricarinate on disc, all 3 carinae well developed, lateral ones diverging towards apex; each lateral margin with a conspicuous carina running from eye to tegula. Mesonotum very deeply and conspicuously depressed on disc, the concavity bordered on sides by nearly straight, strongly elevated submarginal carinae, which converge towards apex, meeting on a rounded tip; lateral margins depressed, evenly rounded posteriorly; tip of scutellum rounded. Hind tibiae unarmed. Pregenital plate roughly trapezoidal, about as wide as long, basal border concavely curved, sides widening to about two-fifths from base, then gradually tapering posteriorly, angles obtusely rounded, surface with a shallow

depression on basal half and two smaller ones on apical half, at sides with short, scattered hairs.

Tegmina with sides expanding apically for about three-fifths of length, nearly symmetrically rounded at tip, length a little over two times greatest width; margin completely bordered, border widened below stigma, where it is also transversely rugose. Costal cell wide, feebly expanding toward apex; Sc and R joined to stigma; basal cell small, elongate; 7 apical cells; first trapezoidal, with inner side concavely curved, large; second trapezoidal; third smaller, triangular; fourth elongate, rectangular, medio-apical; fifth triangular, subequal to third; sixth and seventh pentagonal, the latter with upper inner side slightly concavely curved, and with one angle touching tip of clavus. Four small ante-apical cells, three with sides curved.

Anal segment of male bifid; aedaegus with 2 sclerotized rods and a pair of dorso-lateral spine-like processes; genital styles with a lateral eminence.

Genotype *Paraprosoptropis monensis*, n. sp.

This genus is closely related in many ways to *Prosoptropis* Uhler, from the Lesser Antilles. *Paraprosoptropis* differs from this and from all other described genera of West Indian Kinnaridae in several ways, principally in having the disc of the mesonotum depressed, and in possessing 4 ante-apical cells in the tegmina.

Paraprosoptropis monensis, n. sp. Figs. 5, 6, 7, 8, and 9.

Vertex pale yellow, with posterior median region orange chrome; frons pale stramineous, a large orange chrome patch occupying most of upper area and gradually narrowing apically along sides of median carina; clypeus deep orange; eyes whitish, a small spot on upper inner region and emargination purplish; second joint of antennae pale yellow. Pronotum pale stramineous, a wide band of dark orange on basal half not reaching sides. Mesonotum dark orange on basal half, apical half very pale stramineous. Scutellum dark orange, tip pale stramineous. Tegmina hyaline, with 2 fuscous spots at base of clavus, first largest, second very small; 3 on costal area, middle one very large; an oblique fuscous band from base of seventh apical cell to base of first; a small fuscous spot between the first and second apical cells, on the border and another similarly placed between the sixth and seventh apical cells; and a large fuscous patch on the apical border; veins fuscous. Entire abdomen dark orange, edges of last 2 segments and anal segment very pale stramineous. Subgenital plate pale orange, narrowly infuscated on the edges and very faintly so on apical third. Legs pale stramineous, femora infuscated on the edges and very slightly so on apical half.

Anal segment of male very large, curving inwardly at apex which is forked; aedaegus short and broad, slightly curved upward; genital styles

irregularly sinuate on dorsal margin which is also setose, ending in a short, obtuse, upwardly curved hook; lateral eminence large, with a deep sinus on upper margin which is setose, terminating in a rounded point.

Length, female .94 mm.; tegmen 1.40 mm.; male .88 mm.; tegmen 1.31 mm.

Holotype, female, Mona Island, August 11–31, 1944.

Allotype, male, Mona Island, April 7, 1944.

Family TROPIDUCHIDAE

Neurotmeta viridis Walker

Wolcott 1941: 53 records one specimen at light at Sardinera Beach, March 29, 1940. The writer has numerous specimens collected from weeds at Uvero Beach, April 5 and June 29, 1944.

Family FLATIDAE

Petrusa marginata Brunnich. Figs. 18 and 19.

Wolcott 1941: 53 records the dark form of this species (as *Ormenis marginata* Brunnich) on *Coccolobis uvifera*, *Coccolobis laurifolia*, and *Lantana*, and at light at Sardinera Beach, Camp Cofresí and Uvero Beach, August 5–7, 1939. He gives the same records for the pale form which he reports as *O. pygmaea* Frabricius. The writer has numerous specimens of both forms collected by sweeping on weeds at Uvero and Sardinera Beaches, March 4 and April 4–7, 1944.

The writer is following Fennah 1941: 193–195 and others, who regard *marginata* and *pygmaea* as a single species since both forms merge in coloration and have very similar genitalia.

Melormenis antillarum Kirkaldy

Recorded by Wolcott 1941: 53 (as *Ormensis quadripunctata* Fabricius) on *Coccolobis uvifera* at Playa de Pájaros, August 8, 1939. The writer has specimens swept from weeds at Uvero, April 7, 1944. The internal male genitalia are shown in figs. 14 and 17.

Flatoidinus pseudopunctatus, n. sp. Figs. 10, 11, 12, 13, and 15.

Head much narrower than pronotum. Vertex about two times as wide as length at middle, obtusely pointed anteriorly; lateral margins slightly arcuate; surface flat, with a T-shaped furrow on disc. Frons one and a quarter times longer than greatest width; base as wide as apex, obtusely pointed; sides evenly arcuate, with a prominent, elevated marginal carina becoming obsolete apically; apical margin straight; surface gradually curved downward, slightly depressed on median apical half and conspicuously tumid on median basal portion. Clypeus longer than width at base (1.4 to 1); sides converging apically and nearly straight; surface convex.

Pronotum slightly longer than vertex; a strongly elevated marginal carina on sides, behind eyes; hind border deeply and evenly emarginate; two large punctures on disc. Mesonotum very large; length at middle about equal to greatest width; front margin acutely rounded; hind margin gradually narrowing into an obtuse point, tip slightly raised; surface convex, disc slightly depressed. Tegmina long and broad, a little over two and a quarter times longer than wide; apical border broadly rounded; costal membrane almost reaching apex, about two times broader than costal cell, gradually narrowing posteriorly, with numerous transverse veins; 3 irregular subapical lines, not reaching costal margin. Front tibiae grooved on outer side, distally enlarged, with 3 ante-apical spines; middle and posterior tibiae trilateral.

General color yellowish-brown, underparts lighter; frons infuscated basally; mesonotum fuscous brown; tegmina slightly infuscated apically and along outer border of clavus; wings smoky-hyaline. Vertex with a narrow, longitudinally elongate fuscous spot on each side of median line; pronotum with the two fuscous punctures on disc and several fuscous spots behind eye; mesonotum and tegmina with scattered small fuscous markings.

Length to apex of tegmina, male, 8.43 mm.; female 8.23 mm.

Holotype, male, swept from weeds, Sardinera Beach, Mona Island, April 4, 1944.

Allotype, female, swept from weeds, Sardinera Beach, Mona Island, April 7, 1944.

Paratypes, 4 males, Mona Island, April 4–5, 1944.

The records given by Wolcott 1941: 53 under *Flatoides punctatus* Walker, an entirely different flatid, should be referred to this species. He reported specimens taken at light, Camp Cofresí, August 6, 1939, on *Coccolobis uvifera*, *Coccolobis laurifolia*, and casuarina pines, August 6–7, 1939, and on "corcho" and "alelí" on the plateau, April 1, 1940.

Family ACANALONIIDAE

Acanalonia brevifrons Muir

One specimen swept from weeds on the plateau, June 29, 1944.

Acanalonia pumila Van Duzee

The writer found nymphs and adults of this species exceedingly abundant on *Mallotonia gnaphaloides* at Sardinera Beach, April 4, 1944.

Family ISSIDAE

Colpoptera maculata Dozier

Wolcott 1941: 53 reports one specimen collected at Sardinera Beach, March 30, 1940.

Colpoptera flavifrons Osborn

The writer has numerous specimens swept from weeds at Sardinera and Uvero Beaches, March 4 and April 7, 1944. The male genitalia are shown in fig. 16.

Family CHERMIDAE

Ceropsylla sideroxyli Riley

Listed from Mona by Wolcott 1941: 54, on *Sideroxylon foetidissimum.*

Family APHIDIDAE

Aphis gossypii Glover

Wolcott 1941: 54 reports heavy infestations of watermelons by this aphid at Rancho Grande, March 31, 1940.

Macrosiphum ambrosiae Thomas

Martorell found this aphid on the leaves and branches of *Salvia splendens* which undoubtedly is an error for *Pluchea purpurascens* ("salvia" in Spanish) since that plant is not found in Mona. The author found the species on the tender leaves and stems of *Pluchea* at Sardinera and Uvero Beaches on April 5, 1944.

Family ALEYRODIDAE

Aleurothrixus floccosus Maskell

Wolcott found this species under the leaves of *Coccolobis uvifera* at Uvero Beach, April 7, 1944.

Family COCCIDAE

Icerya purchasi Maskell

Introduced into the island probably in the Australian pines planted by the Forestry Service at Sardinera Beach. First reported by Wolcott 1939: 33. Martorell observed a heavy infestation of the scale on casuarina pines and cultivated eggplants at Camp Cofresí and Rancho Grande Sardinera Beach, August 5, 1939 (Wolcott 1941: 56). The writer observed very few scales on the casuarina pines during his trip of April 4–7, 1944.

Ceroplastes sp.

A single, very large specimen, white and slightly pinkish, determined by Dr. G. N. Wolcott as a species of *Ceroplastes*, was collected by him on a leaf of *Coccolobis uvifera* at Uvero Beach, April 5, 1944.

Coccus viridis Green

Recorded by Wolcott 1941: 59 at Sardinera Beach on eggplants, *Terminalia Catappa*, *Coccolobis uvifera* and *C. laurifolia*, August 5–6, 1939.

The author found this species at the same locality on April 5, 1944 on the tender stems of *Rawolfia nitida*, attended by *Solenopsis geminata.*

Saissetia oleae Bernard

Wolcott 1941: 60 reports this scale insect, attended by *Solenopsis geminata*, infesting the leaves of *Terminalia Catappa* at Sardinera Beach, August 6, 1939. The author noted the species on the stems of wild cotton at Uvero Beach, April 5, 1944.

Pseudaulacaspis pentagona Targioni

Very scarce during the writer's trip to the island in April, 1944. The accidental occurrence of *Chilocorus cacti* on Mona is held responsible for the scarcity of this and other scale insects on the island by Wolcott 1944: 451–452.

Pinnaspis minor Maskell

Observed on cultivated eggplants at Rancho Grande, attended by *Solenopsis geminata*, August 8, (Acc. No. 119–39) and on mahogany at Camp Cofresí, August 6, 1939 (Acc. No. 120–39). Not very abundant but present on numerous plants, April 5, 1944 (Acc. No. 44–44).

Aspidiotus destructor Signoret

Wolcott 1941: 61 reports this scale abundant on *Barringtonia asiatica* and on cocoanuts at Sardinera Beach, August 5, and on the fruits and leaves of the first host at Playa de Pájaros, August 7, 1939. The writer observed the species heavily infesting the leaves of *Barringtonia* at Sardinera Beach, April 7, 1944, and also noted *Chilocorus cacti* feeding on them.

Pseudoparlatoria ostreata Cockerell

Wolcott 1941: 62 records this scale on the stems of wild papayas all over the island. During the writer's trip in April, 1944, the scale was very scarce, and was noted only on one occasion on which larvae and pupae of *Chilocorus* were also present.

Order Hemiptera

The writer is responsible for most of the determinations in this order.

Family NOTONECTIDAE

Buenoa femoralis Fieber

The only record of this species from Mona Island is that reported by Barber 1939: 421 based on specimens collected by F. E. Lutz on February 21–26, 1914.

Buenoa pallipes Fabricius

This is another species known only from the island by specimens collected by F. E. Lutz on February 21–26, 1914 and reported by Barber 1939: 421.

Family CORIXIDAE

Trichocorixa verticalis Fieber

Det. R. I. Sailer

Found abundantly in several small ponds of stagnant water along Sardinera Beach, April 6 and August 11–31, 1944. This is a North American species which has not been found yet in Puerto Rico itself. It can be easily recognized from other species by its robust form and the large frontal depression of the males.

Family VELIIDAE

Microvelia robusta Uhler

First recorded from the island by Barber 1939: 411 from specimens collected by F. E. Lutz on February 21–26, 1914. Numerous apterous and winged specimens were taken from a small pool at the airfield on April 6, 1944.

Family GERRIDAE

Limnogonus franciscanus Stål

This is a common species in Puerto Rico and other West Indian islands. It was first reported from Mona Island by Barber 1939: 408 (February 21–26, 1914; F. E. Lutz). Wolcott 1941: 65 reports it as common in a pool and cistern at Sardinera Beach, August 5, 1939 and March 31, 1940. Several specimens were collected by the author in a pool at the same locality on April 4–7, 1944.

Family MIRIDAE

Pycnoderes quadrimaculatus Guerin

Martorell recorded this species on field beans at Sardinera Beach on August 6, 1939 (Acc. No. 171–39). A single specimen in the writer's collection was collected at light at Sardinera Beach on April 5, 1944.

Lygus apicalis Fieber

Wolcott 1941: 66 reports specimens collected at light (Acc. No. 377–39).

Polymerus cuneatus Distant

Several specimens were collected by the writer by sweeping on weeds at Uvero Beach, April 4, 1944.

Creontiades rubrinervis Stål

A single specimen swept from weeds at Uvero Beach, April 4, 1944, others taken at Sardinera on June 29, 1944.

Family ANTHOCORIDAE

Cardiastethus rugicollis Champion

Several specimens taken by sweeping on weeds, Sardinera Beach, April 4–6, 1944.

Asthenidea picta Uhler

Det. R. I. Sailer

Two specimens swept from herbage, Uvero Beach, August 11–31, 1944.

Xylocoris sordidus Reuter

Known from Mona Island only from specimens collected by F. E. Lutz on February 21–26, 1914 and reported by Barber 1939: 401.

Family CIMICIDAE

Cimex hemipterus Fabricius

The common tropical bedbug was observed by Martorell on beds at Camp Cofresí on March 28, 1940 and reported by Wolcott 1941 : 67.

Family NABIDAE

Nabis capsicornis Germar

This cosmopolitan species is represented in the writer's collection of Mona Island insects by a single specimen taken by sweeping on herbage at Uvero Beach, August 11–31, 1944.

Family REDUVIIDAE

Zelus longipes Linnaeus

This species, although one of the most abundant reduviids in Puerto Rico, is rather uncommon in Mona Island. A single specimen in the collection of the College of Agriculture at Mayaguez, Puerto Rico is dated April 5, 1935. Wolcott 1941 : 68 records one specimen feeding on *Cycloneda sanguinea* on August 5–7, 1939. There is another specimen in the author's collection, taken from weeds at Sardinera Beach, August 11–31, 1944.

Family PHYMATIDAE

Macrocephalus sp.

A single nymph collected on weeds at Sardinera, August 11–31, 1944, has been placed in this genus because the characters of the antennae and front legs.

Family TINGIDAE

Corythucha gossypii Fabricius

Recorded by Wolcott 1941: 71 on castor bean, August 8, 1939. The writer found it common at Sardinera, April 4, 1944, all stages infesting the undersides of the leaves of *Capparis flexuosa* and *Ricinus communis*.

Teleonemia prolixa Stål

Several specimens taken from weeds at Uvero Beach, April 5, and August 11–31, 1944, agree with specimens of *T. prolixa* from Puerto Rico, determined by H. G. Barber.

Family PYRRHOCORIDAE

Dysdercus andreae Linnaeus

Known only from specimens taken on February 21–26, 1914 by F. E. Lutz and reported by Barber 1939: 336.

Family LYGAEIDAE

Oncopeltus aulicus Fabricius

Recorded by Wolcott 1941: 73 on *Ricinus* at Rancho Grande, August 1939, and on blossoms of *Colubrina colubrina*, *Moringa moringa*, and *Pisonia albida* at the same locality on March 31, 1940. Not collected by the writer.

Oncopeltus semilimbatus Stål

Barber 1939: 336 lists a specimen in the American Museum of Natural History collected on the island on November 10, 1919. The writer has specimens swept from weeds at Uvero Beach on the following dates: April 1935; July 19 and August 11–31, 1944.

This species is very closely related to the above but, as pointed out by Barber 1939: 336, it can be readily separated from it by the difference in coloration. In *aulicus* the entire lateral margins of the pronotum and the tip of the scutellum are red; the premedian white discal spot of the membrane is reduced to a narrow white line; and the apical and outer margins of the membrane are narrowly white. In *semilimbatus* the black area of the pronotum is extended to the lateral margins so that they are not entirely red; the tip of the scutellum is black; the premedian white discal spot of the membrane is narrowly whitish.

Although recorded from other of the Greater Antilles and Mona Island, this species has not yet been reported from Puerto Rico itself.

Lygaeus (Craspeduchus) pulchellus Fabricius

This is the most common *Lygaeus* in the island. Barber 1939: 337 reports specimens collected on February 21–26, 1914 and on April 6, 1924.

The writer found it abundantly on several weeds on April 4–6, 1944. He has also numerous specimens dated March and August 11–31, 1944.

Lygaeus (Ochrimnus) collaris Fabricius

This species is not common in the island. Wolcott 1941: 72 records it on flowers of *Pisonia albida* on April 2, 1940. The writer collected a single specimen by sweeping on weeds, April 4, 1944.

Lygaeus (Melanocoryphus) albonotatus Barber

This small and interesting species was described by Barber 1923: 2 from a single specimen collected on February 24, 1914. This unique specimen is deposited in the American Museum of Natural History. The writer was not able to collect this species during his trips to the island in spite of very diligent search for it.

Nysius ericae Schilling

This widely distributed species was first collected on the island on February 21–26, 1914 by H. E. Crampton. This record is reported by Barber 1939: 342. The writer has specimens dated April 1935 and July 20, 1944.

Nysius inaequalis Uhler

Barber 1939: 341 reports specimens collected by Crampton on February 22, 1914. The writer has a single specimen collected by him from herbage on April 1935.

Nysius strigosus Uhler

Known only from specimens collected on the island on February 21–26, 1914 by F. E. Lutz and reported by Barber 1939: 342.

Ischnorhynchus championi Distant

Collected by H. E. Crampton, February 15, 1914, as reported by Barber 1939: 344. The writer found it exceedingly abundant at Sardinera and Uvero Beaches, April 4–7, 1944, where he obtained numerous specimens by sweeping on shrubbery and low herbage.

Blissus leucopterus Say

First recorded from Mona by Barber 1939: 345 from specimens taken by Crampton on February 22, 1914. Wolcott 1941: 73 lists this species from grasses at Rancho Grande, August 7–8, 1939.

Geocoris thoracicus Fieber

One specimen secured by sweeping on weeds on the plateau, July 20, 1944. A second specimen was taken in the same way at Uvero Beach August 11–31, 1944.

Pachygrontha parvula Barber

This species was described by Barber 1923: 4 from a single male collected on the island on February, 1914. This specimen is in the collection of the American Museum of Natural History.

Paromius longulus Dallas

Known from Mona only by the specimens collected there by F. E. Lutz on February 21–26, 1914 and reported by Barber 1939: 350.

Pachybrachius vinctus Say

Collected by F. E. Lutz on February 21–26, 1914 (Barber 1939: 353). Three specimens in the author's collection were taken on weeds at Sardinera Beach, August 11–31, 1944.

Pachybrachius scutellatus Dallas

The following specimens in the author's collection were secured from Mona Island: April 1935 (Det. H. G. Barber); April 7, 1944 (at light); August 11–31, 1944 (swept from weeds).

Heraeus guttatus Dallas

Two specimens were collected at light, Sardinera Beach, April 5, 1944. This species was previously known from Puerto Rico only by a single specimen collected at Isabela, April 24, 1930.

Ozophora atropicta Barber

Numerous specimens taken at light, Sardinera Beach, April 4–7, 1944.

Ozophora octomaculata, n. sp. Fig. 20.

Head black, with numerous short, appressed, whitish hairs on anterior dorsal surface, dorsal median area and undersurface; with 10 long setae between eyes and several shorter ones at tip of tylus; tylus ferrugineous; eyes with a reddish tinge principally around base; ocelli bright red; antennae with basal segment ferrugineous, segments II and III stramineous, and terminal one brownish; rostrum ferrugineous. Pronotum black, with 8 conspicuous, yellowish-orange, calloused spots placed as follows: 2 small, transversely elongated ones on collar; 4 larger and rounded ones equidistantly placed on disc of posterior lobe, lower ones reaching hind border of pronotum; and 2 largest ones on humerals. Scutellum black, with 2 submarginal inconspicuous, yellowish spots on disc parallel to sides; tip white. Hemelytra fuscous, with commissure, narrow costal margin, and radius yellowish-white, and with claval suture, claval vein and media, brownish-white; membrane smoky brown, with veins, inner basal angle, and broad apical margin whitish. Underparts black; venter with castan-

eous tinge and with numerous long hairs principally on hind border of last segments. Femora ferrugineous; tibiae and tarsi stramineous.

Head wider than long (.96 x .86 mm.). Length of antennal segments as follows: I, .53; II, 1.53; III, 1.10; IV, 1.60 mm. Rostrum extending to hind border of first visible abdominal segment; length of segments as follows: I, .90; II, 1.03; III, .73; and IV, .43 mm. Pronotum about one-third shorter than wide (1.10 x 1.56 mm.); anterior lobe slightly shorter than posterior lobe; disc of anterior lobe smooth except for a few very fine and inconspicuous punctures on median region and on sides; posterior lobe deeply and rather closely punctate except for calloused spots on humeral angles and on disc. Scutellum a little longer than wide (.83 x .76 mm.), much shorter than pronotum but distinctly longer than commissure; disc shallowly but distinctly sunken, rather deeply and closely punctate; region surrounding submarginal calloused spots impunctate; lateral submargins depressed, with 2 rows of close punctures. Hemelytra with costal margin very slightly concavely sinuate about one-third away from base; clavus with 6 rows of close punctures; corium also rather closely punctate along the subcostal area and along the borders of the veins. Anterior femora swollen, with 5 spines below on apical half. Length 5.60 mm.; width across humerals 1.56 mm.

Holotype, male, collected at light, Sardinera Beach, Mona Island, April 4, 1944.

Paratypes, 7 males and 2 females with same data as type; 6 males and 2 females, some data as type but April 5; and 2 males and 2 females, same data as type but April 7.

This species ressembles *O. subimpicta* Barber and *O. quinquemaculata* Barber in size and shape but it can be readily distinguished from them by the 8 conspicuous yellowish-orange spots on the pronotum which give the species its name.

Paragonatas divergens Distant

A single specimen taken at light, Sardinera Beach, March 5, 1944.

Family NEIDIDAE

Jalysus reductus Barber

This small stilt bug was described by Barber 1939: 331 from numerous specimens from the West Indies and Central America. The type, a male deposited in the American Museum of Natural History, was collected on Mona Island, February 21–26, 1914, by F. E. Lutz.

Family COREIDAE

Phthia picta Drury

Collected by Martorell on eggplants at Rancho Grande, August 8, 1939 (Wolcott 1941: 75).

Catorhintha guttula Fabricius

This is a rather common species in Mona. F. E. Lutz collected it on February 21–26, 1914 (Barber 1939:318). In the author's collection there are numerous specimens from the island dated as follows: April, 1935; April 4–7, July 19, and August 11–31, 1944. Martorell recorded the species as abundant on corn leaves at Camp Cofresí, August 7–8, 1939 (Acc. No. 100–39).

Sphictyrtus whitei Guérin-Méneville

This beautiful large coreid, known locally as "avispilla" because of the wasp-like flight and buzzing sound produced when disturbed, is extremely abundant on Mona Island. Barber 1939: 321 lists specimens taken there on December 20, 1913; February 21–26, 1914; September 10, 1919; and March 10, 1926. Sein noted adults feeding on corn in 1926 but did not succeed in finding the nymphs or eggs (Wolcott 1936: 173). Wolcott 1941 : 76 records the species as common on August 5–9, 1939 and again in 1940, remarking: "Adults in swarms clinging to lower branches of trees in shade of cliff, no apparent preference as to kind of tree, and not feeding. At top of cliff, adults on tender leaves of *Coccolobis laurifolia*, possibly feeding". The writer did not observe the species during his trip to the island in April, 1935, but found it abundantly on coconut palms and other plants at Sardinera Beach on April 4–7, 1944. He also observed adults feeding on the flowers of *Colubrina colubrina* on that occasion.

The species was described from Cuba in 1857 and has also been reported from San Salvador, Bahamas. It is not known from the Puerto Rican mainland.

Leptocorisa filiformis Fabricius

Wolcott 1941 : 76 lists one specimen taken on weeds at Sardinera, August 8, 1939.

Hyalmenus longispinus Stål

Barber 1939: 323 records this species from Mona based on specimens collected by F. E. Lutz on February 21–26, 1914.

Corizus (Liorhyssus) hyalinus Fabricius

This common and widely spread species was first recorded from the island by Barber 1939: 327, who reports specimens taken on February 21–26, 1914 by F. E. Lutz. The writer has numerous specimens swept from weeds at Sardinera and Uvero Beaches, August 11–31, 1944.

Corizus sidae Fabricius

F. E. Lutz secured specimens on February 21, 1914, as reported by Barber 1939: 327. The writer collected several specimens (Det. H. G. Barber) in April, 1935.

Jadera haematoloma Herrich-Schaeffer

Numerous nymphs and adults of this species were collected by the author at Uvero Beach on April 5, 1944 under dead leaves and on the dry culms of guinea grass. This is a continental species which, according to Blatchley 1926: 286, was previously known only from Cuba in the West Indies. The species is readily distinguished from other species of *Jadera* in the West Indian region by the red and black color and conspicuous median carina on the pronotum.

Family PENTATOMIDAE

Mormidea angustata Stål

Barber 1939: 288 reports specimens collected by F. E. Lutz on February, 1914. This Mexican species is also known from the Isle of Pines and the Puerto Rican mainland in the West Indies.

Thyanta perditor Fabricius

Barber 1939: 292 reports specimens collected by F. E. Lutz on February 21–26, 1914. The author collected a single specimen on the island in April, 1935.

Thyanta antiguensis Westwood

A single specimen collected by sweeping on weeds, Sardinera Beach, August 11–31, 1944.

Nezara viridula Linnaeus

Wolcott 1936: 77 lists this species from Mona (Acc. No. 1319–13). Martorell collected one specimen at light at Camp Cofresí, August 7, 1939, and several others from weeds on the plateau, March 30, 1940 (Wolcott 1941: 78). The writer has numerous specimens from different localities on the island with the following dates: April, 1935; April 4, June 29, July 19 and 20, and August 11–31, 1944.

Acrosternum marginatum Palisot de Beauvois

Wolcott 1941: 78 reports specimens at light, Camp Cofresí and on weeds at Rancho Grande, August 7–8, 1939. The writer collected specimens on weeds at Sardinera Beach, April 5, 1944.

Arvelius albopunctatus DeGeer

Martorell collected a single specimen on eggplants at Rancho Grande, August 7, 1939. (Wolcott 1941: 78).

Brepholoxa rotundifrons Barber

A single specimen collected on weeds on the plateau, August 11–31, 1944.

Podissus sagitta Fabricius

One specimen collected on weeds, Sardinera Beach, August 11–31, 1944.

Pachycoris fabricii Linneaus

The author collected specimens on Mona, April, 1935. He has other specimens collected by sweeping on weeds on the plateau, March 5, 1944.

Diolcus irroratus Fabricius

Specimens collected on weeds, April, 1935 and April 5 and July 20, 1944.

Order COLEOPTERA

Family CARABIDAE

Tachys ensenadae Mutchler

Det. J. M. Valentine

At light, Sardinera Beach, April 5, 1944; under dead leaves near cliff, Uvero Beach, August 11–31, 1944.

Tachys sp.

Det. J. M. Valentine

A single specimen under trash near cliff, Uvero Beach, August 11–31, 1944.

Tetragonoderus sp.

Det. J. M. Valentine

Numerous specimens taken on the ground, Sardinera Beach, August 11–31, 1944.

Selenophorus sinuatus Gyllenhall

Det. P. J. Darlington, Jr.

Several specimens, April, 1935 and August 11–31, 1944.

Seleneophorus alternans Dejean

Det. J. M. Valentine

Many specimens under stones and dead leaves near the cliff, Sardinera Beach, August 11–31, 1944.

Selenophorus sp.

A single specimen collected at light, Sardinera Beach, April 1, 1940 (Acc. No. 289–40).

Apenes sp.

A single specimen at light, Sardinera Beach, March 7, 1944.

Family DYTISCIDAE

Copelatus angustatus Chevrolat

At light, Sardinera Beach, June 29 and July 22, 1944. Many specimens from a small pool near the airfield, August 11–31, 1944.

Rhantus calidus Fabricius

Det. L. L. Buchanan

One specimen at light, Sardinera Beach, August 11–31, 1944.

Thermonectes circumscripta Latreille

Specimens taken in a small pool near the airfield, August 11–31, 1944.

Family HYDROPHILIDAE

Enochrus nebulosus Say

Specimens at light, Sardinera Beach, April 6 and June 29, 1944.

Berosus interstitialis Knisch

A single specimen at light, Sardinera Beach, April 6, 1944; others from a small pool near the airfield, August 11–31, 1944.

Hydrophilus ater Olivier subsp. **intermedius** DuVal

One specimen at light, Sardinera Beach, June 29, 1944.

Tropisternus lateralis Fabricius

Several specimens from a small pool near airfield, August 11–31, 1944.

Cercyon sp.

A single specimen at light, Sardinera Beach, April 4, 1944.

Family HISTERIDAE

Omalodes klugi Marseul

One specimen at Sardinera Beach, June 29, 1944.

Saprinus sp.

Det. H. S. Barber

Many specimens under a dead bird, Sardinera Beach, April 6–7, 1944.

Family STAPHYLINIDAE

Oxytelus incisus Mots.

Det. R. E. Blackwelder

Many specimens collected under a dead bird, Sardinera Beach, April 6–7, 1944.

Lithocharis sp.
Det. R. E. Blackwelder
Many specimens under trash, Sardinera Beach, June 29 and August 11–31, 1944.

Philonthus havaniensis Laporte
Det. R. E. Blackwelder
Numerous specimens under trash, Sardinera Beach, June 29, 1944.

Philonthus ventralis Gravenhorst
Det. R. E. Blackwelder
Several specimens under a dead bird, Sardinera Beach, April 4, 1944.

Cafius bistriatus Erichson
Listed from Mona by Blackwelder 1944: 135. One specimen (Det. R. E. Blackwelder) collected under trash, Sardinera Beach, August 11–31, 1944.

Cafius subtilis Cameron
Det. R. E. Blackwelder
Many specimens under trash, Sardinera Beach, August 11–31, 1944.

Xantholinus beattyi Blackwelder
Det. R. E. Blackwelder
Several specimens under a dead bird, Sardinera Beach, April 4, 1944.

Family CANTHARIDAE

Tytthonyx cavicornis Leng and Mutchler
Described by Leng and Mutchler 1922: 489 from a single specimen taken by F. E. Lutz on February 26, 1914. The type is in the collection of the American Museum of Natural History. The writer has 3 specimens swept from shrubs on the plateau, April 5 and June 29, 1944.

Tylocerus barberi Leng and Mutchler
One specimen at light, Sardinera Beach, March 3, 1944.

Family MELYRIDAE

Melyrodes sp.
Det. H. S. Barber
One specimen, Sardinera Beach, August 11–31, 1944.

Family CORYNETIDAE

Necrobia rufipes DeGeer
Numerous specimens taken on decaying fish at Sardinera Beach, March 6, 1944. Others on a dead goat on the plateau, April 7, 1944.

Family ELATERIDAE

Adelocera rubida Schwarz
Described by Schwarz 1902: 193.

Conoderus figuralis Candeze
Det. M. C. Lane
Three specimens swept from weeds, Sardinera Beach, April 7, 1944.

Conoderus sericatus Candeze
Det. M. C. Lane
Numerous specimens at light, Sardinera Beach, March 1–5, April 4–7, and July 20, 1944.

Drasterius elegans Fabricius
Det. W. S. Fisher
At light, Camp Cofresí, March 31, 1940 (Acc. No. 280–40).

Dicrepidius ramicornis Palisot de Beauvois
Wolcott 1941 : 88 lists one specimen taken on *Ricinus* at Camp Cofresí, August 7, 1939.

Esthesopus poedicus Candeze
Det. J. M. Valentine
One specimen swept from vegetation, Sardinera Beach, August 11–31, 1944.

Family BUPRESTIDAE

Acmaeodera gundlachi Fisher
Wolcott 1941 : 88 reports one specimen resting on weeds at Camp Cofresí, Sardinera Beach, August 7, 1939. The author has several specimens collected on flowers and on weeds at Uvero Beach, April 7, May 24, and August 11–31, 1944.

Polycesta thomae Chevrolat
Martorell and the writer collected larvae, pupae and adults from the dead stems of casuarina pines at Sardinera Beach, April 6, 1944.

Chrysobothris megacephala Castelnau and Gory
One specimen resting on a branch of *Solanum verbascifolium* at Uvero Beach, April 7, 1944.

Micrasta oakleyi Fisher
Two specimens (Det. W. S. Fisher), April, 1935. One specimen on castor bean leaf at Rancho Grande, August 8, 1939 (Wolcott 1941: 89).

Family DERMESTIDAE

Dermestes canina Germar

Wolcott 1941: 89 reports larvae and adults in the shell of a dead turtle and on goat hides at the Lighthouse, April 1, 1940. Numerous larvae and adults were collected by the author on dead fish at Sardinera Beach, April 4–6, 1944.

Family OSTOMATIDAE

Tenebroides mauritanica Linnaeus

Wolcott 1941: 89 records one specimen at light, Camp Cofresí, August 7, 1939. The writer has in his collection another specimen also taken at light on the same locality, March 4, 1944.

Family NITIDULIDAE

Carpophilus sp. (**dimidiatus** Fabricius?)

Det. E. A. Chapin

Numerous specimens collected at Sardinera Beach, August 11–31, 1944.

Haptoncus luteolus Erichson

Recorded by Wolcott 1941: 90 at light (Acc. No. 379–39). Numerous specimens (Det. E. A. Chapin) taken at Sardinera Beach, August 11–31, 1944.

Stelidota strigosa Gyllenhall

Det. E. A. Chapin

One specimen taken at Sardinera Beach, August 11–31, 1944.

Family MONOTOMIDAE

Europs sp.

Det. W. S. Fisher

Several specimens swept from vegetation, Sardinera Beach, August 11–31, 1944.

Family CUCUJIDAE

Ahasverus (**Cathartus**) **advena** Waltl

One specimen under the bark of a dead tree, Camp Cofresí, August 9, 1939 (Wolcott 1941: 90).

Ahasverus rectus LeConte

Det. W. S. Fisher

Many specimens, Sardinera Beach, August 11–31, 1944.

Family EROTYLIDAE

Mycotretus sp.

Det. W. S. Fisher

Martorell obtained specimens at light at the Lighthouse, April 1, 1940.

Family CRYPTOPHAGIDAE

Loberus sp.

Det. W. S. Fisher

Martorell observed this species on watermelons at Rancho Grande, March 30, 1940. The writer collected numerous specimens by sweeping on weeds at Sardinera and Uvero Beaches, April 4 and August 11–31, 1944.

Family PHALACRIDAE

Acylomus sp.

Reported by Wolcott 1941: 91 as taken at light (Acc. No. 379–39).

Family MYCETOPHAGIDAE

Typhaea stercorea Linnaeus

Det. W. S. Fisher

Specimens at Sardinera Beach, June 29, 1944.

Family COCCINELLIDAE

Scymnus roseicollis Mulsant

On castor bean at Rancho Grande, August 8, 1939 (Wolcott 1941: 92). One specimen swept from vegetation, Uvero Beach, August 11–31, 1944.

Scymnus floralis Fabricius

Swept from herbage at Sardinera and Uvero Beaches; also on the plateau, March 1, June 29, and August 11–31, 1944.

Scymnus sp.

Two specimens taken on April, 1935.

Rodolia cardinalis Mulsant

Introduced to control *Icerya purchasi*. Martorell reports empty cocoons on casuarinas but not a single adult seen at Camp Cofresí, August 5, 1939 (Acc. No. 125–39). On March 29, 1940 he found it very abundant and well established (Acc. No. 245–40). Wolcott found empty pupal skins abundant and a few live ones on April 5, 1944. He remarks that control of the scale was 99 per cent effective but always enough surviving to maintain both scales and predators (Acc. No. 32–44).

Psyllobora nana Mulsant

Specimens taken on weeds, April, 1935; March 3, and April 4, 1944. Also at light, April 5, 1944.

Psyllobora lineola Fabricius

Many specimens taken on weeds, April, 1935.

Cycloneda sanguinea Linnaeus

Numerous specimens swept from vegetation, April, 1935 and March 4, 1944. Wolcott 1941 : 92 reports this species common on weeds.

Chilocorus cacti Linnaeus

This ladybeetle, not previously known from Mona, was first observed there by Wolcott, Martorell and the writer on April 4–7, 1944, when several adults and pupae were noted at Sardinera and Uvero Beaches on previously scale-infested wild papayas and a single plant of *Barringtonia asiatica*. Wolcott and Martorell 1944: 451–452 believe that the species probably reached Mona by its own initiative from the Puerto Rican mainland, where it was introduced from Cuba and Texas to control scale insects. Additional specimens were also obtained from the same localities on August 11–31, 1944.

Family OEDEMERIDAE

Copidita (Asclera) litoris Wolcott

A single specimen taken at light, Sardinera Beach, March 4, 1944, and determined by Dr. J. M. Valentine as *Copidita* (*Asclera*) sp., agrees perfectly with the species described by Wolcott 1936: 206 as *Oxacis litoris* from specimens collected on the beach of the north coast of Puerto Rico.

This rather small, very slender and elongate beetle has the prothorax dark iridescent green; the elytra are purplish, with the inner margin somewhat yellowish, and the legs dull yellowish orange.

Copidita (Asclera) sp. a.

Det. J. M. Valentine

A single specimen at light, Sardinera Beach, July 20, 1944. The entire beetle is dull violet-blue in color.

Copidita (Asclera) sp. b.

Det. J. M. Valentine

One specimen at light, Sardinera Beach, June 29, 1944; others swept from weeds at the plateau, August 11–31, 1944. This is a purplish species with the prothorax brownish red, the eyes and antennae nearly black and the elytra with the outer margins and a median longitudinal ridge whitish.

The beetles are identical with specimens from Desecheo Island (about 30 miles northeast of Mona) in the collection of the College of Agriculture, Mayaguez, Puerto Rico, determined as *Ditylus* sp. nov. by Dr. A. J. Mutchler.

Oxacis geniculata Chevrolat

Det. J. M. Valentine

Numerous specimens taken at light, Sardinera Beach, March 4–6 and April 5–6, 1944. This is the second most abundant and the largest oedemerid on the island. The head, except for the black eyes and infuscated basal segment of the antennae, and the entire prothorax are yellowish. The abdomen and elytra, except the outer and inner margins, are greyish-blue. The legs are light yellow, with the apical half of the femora strongly infuscated.

Alloxacis sp. a.

Det. J. M. Valentine

Two specimens at light, Sardinera Beach, June 29, 1944. This is a small, slender species of a deep metallic blue color.

Alloxacis sp. b.

Det. J. M. Valentine

This is the most abundant member of the family in Mona Island. The author has numerous specimens dated April, 1935; March 4–6, and April 4–6, 1944 (taken at light, Sardinera Beach). Adults were also observed by him feeding on the pollen of the flowers of *Colubrina colubrina* at the same locality on April 4. The records given by Wolcott 1941: 86 for *Oxacis litoris* probably refer to this species.

This is a very dull and dark blue species, the eyes are black and the antennae, except for the two basal segments, are reddish brown.

Alloxacis sp. c.

Det. J M. Valentine

Specimens at light, Sardinera Beach, March 4, 1944.

In this species, the head, except for the black eyes, the prothorax and scutellum are yellow. The antennae are infuscated on the basal half. The elytra are dull greyish-blue, each with 2 inconspicuous elevated lines. The legs are yellowish, with the apical portion of the femora somewhat infuscated.

Sessinia vittata Fabricius

Det. J. M. Valentine

One specimen swept from weeds at Sardinera Beach, April 7, 1944. Wolcott 1941: 86 reports the species (as *Ananca vittata* Fabricius) very

abundant at light and on sea-grape at Camp Cofresí and Playa de Pájaros, August 7–8, 1939 and March 30, 1940.

Family MORDELLIDAE

Mordellistena sp. a.

Three specimens swept from weeds and low shrubs on the plateau, June 29, 1944.

Mordellistena sp. b.

A single specimen from weeds at Sardinera Beach, August 11–31, 1944.

Family ANTHICIDAE

Anthicus (Omonadus) floralis Linnaeus

Det. J. M. Valentine

Two specimens at light, Sardinera Beach, June 29, 1944.

Family ALLECULIDAE

Hymenorus sp.

Wolcott 1941: 93 reports specimens common at light, Camp Cofresí, and on weeds at the airfield, August 5–6, 1939. The writer has numerous specimens also taken at light at Sardinera Beach, March 4, 1944, and on weeds at Uvero and Sardinera Beaches, April 4, June 29, and July 20, 1944.

Family TENEBRIONIDAE

Opatrinus pullus Sahlberg

Reported by Wolcott 1941: 93 at light, Camp Cofresí, August 5, 1939.

Trientoma varvasi Solier

Specimens swept from vegetation, Uvero Beach, July 21 and August 11–31, 1944.

Blapstinus punctatus Fabricius

Wolcott 1941: 93 reports specimens at light, Camp Cofresí, August 8, 1939. The writer has specimens also taken at light at the same locality on March 7, 1944.

Blapstinus sp.

Det. R. E. Blackwelder

Many specimens taken under trash, Sardinera Beach, March 4, April 5, and August 11–31, 1944.

Phaleria angustata Chevrolat

Det. R. E. Blackwelder

Numerous specimens taken under trash, Sardinera Beach, August 11–31, 1944.

Phaleria variabilis Quedenfeldt

Wolcott 1941: 93 reports specimens at light, Camp Cofresí, August 8, 1939. The writer collected specimens also at light at the same place on April 4, 1944.

Crypticus sp.

Det. R. E. Blackwelder

One specimen at Sardinera Beach, August 11–31, 1944.

Diaperis hydni Fabricius

Martorell and the writer collected one specimen at light, Sardinera Beach, April 7, 1944.

Tribolium castaneum Herbst

Two specimens taken at light, Sardinera Beach, April 7, 1944.

Doliema pallida Say

Wolcott 1941: 94 reports specimens under the bark of *Canella Winteriana* at Rancho Grande, August 8, 1939. The author has specimens taken under the bark of a dead tree at Sardinera Beach, June 29, 1944.

Family CISIDAE

Ceracis sp.

Det. W. S. Fisher

Abundant on fungi at Sardinera Beach, August 11–31, 1944.

Family ANOBIIDAE

Lasioderma serricorne Fabricius

One specimen at light, Sardinera Beach, April 7, 1944.

Family BOSTRICHIDAE

Tetrapriocera longicornis Olivier

Det. W. S. Fisher

One specimen at light, Sardinera Beach, April 7, 1944.

Heterarthron gonagrum Fabricius

First reported from Mona by Leng and Mutchler 1914: 453. The writer has several specimens taken on April, 1935, boring in casuarinas.

Xylomeria torquata Fabricius

Wolcott 1941: 95 reports numerous specimens at light, Camp Cofresí, August 6, 1939.

Family TROGIDAE

Trox suberosus Fabricius

One specimen at light, Sardinera Beach, August 11–31, 1944.

Family SCARABAEIDAE

Aphodius cuniculus Chevrolat

Common at light, Sardinera Beach, March 3–4 and April 4–7, 1944. Also on fresh cow dung at the same locality, April 5, 1944.

Ataenius darlingtoni Hinton

One specimen at light, Sardinera Beach, March 5, 1944.

Ataenius beattyi Chapin

Several specimens taken at Sardinera Beach, August 11–31, 1944.

Ataenius miamii Cartwright

Det. E. A. Chapin

Several specimens collected under trash near the cliff, Sardinera Beach, August 11–31, 1944.

Cnemarachis monana Moser

Described from Mona by Moser 1921: 181. Wolcott 1941: 97 reports adults at light, August 6, 1939 and March 31, 1940. The writer has specimens taken at light, Sardinera Beach, March 2, April 4–5, and June 29, 1944. He collected numerous larvae and pupae at Uvero Beach, April 5, 1944, under the roots of guinea grass.

Ligyrus tumulosus Burmeister

Wolcott 1941: 98 reports many adults collected at light at Camp Cofresí, August 5–7, 1939 and March 29–30, 1940. The author has numerous adults collected also at light at the same place on March 4, April 4–7, June 29 and August 11–31, 1944.

Strataegus barbigerus Chapin

Two specimens, a male and a female, in rotten stump of *Metopium toxiferum* on the plateau above Sardinera, August 7, 1939 (Wolcott 1941: 98). One female specimen at light, Sardinera Beach, August 11–31, 1944.

Family CERAMBYCIDAE

Stenodontes bituberculatus Palisot de Beauvois

Wolcott 1941: 98 reports an adult taken in an old tree stump at Rancho Grande, August 7, 1939.

Methia necydalea Fabricius

Wolcott 1941: 98 reports specimens collected at light, Camp Cofresí, August 6–7, 1939 and at the Lighthouse, April 1, 1940.

Eburia quadrimaculata Linnaeus

Reported by Wolcott 1941: 98 as very abundant at light, Camp Cofresí, August 5–6, 1939. The author has two specimens collected at light at Sardinera Beach, April 4 and June 29, 1944.

Elaphidion conspersum Newman

Two specimens at light, Sardinera Beach, April 4 and 7, 1944.

Elaphidion insulare Newman

Reported by Wolcott 1941: 98 (Acc. No. 13-37) without definite date or locality.

Elaphidion irroratum Linnaeus

Wolcott 1941: 99 reports this species common at light, Camp Cofresí, August 5-6, 1939. The writer has one specimen taken at light, Sardinera Beach, August 11-31, 1944.

Elaphidion spinicorne Drury

Wolcott 1941: 99 reports specimens at light, Camp Cofresí, August 5-6, 1939 and April 1, 1940.

Merostenus attenuatus Chevrolat

One specimen at light, Sardinera Beach, March 30, 1940 (Wolcott 1941: 99).

Cylindera flava Fabricius

Wolcott 1941: 99 reports one specimen at light, Camp Cofresí, August 8, 1939. The writer has another specimen also taken at light at the same locality, August 11-31, 1944.

Lepturges guadeloupensis Fleutiaux and Sallé

Det. W. S. Fisher

One specimen at light, Sardinera Beach, August 11-31, 1944.

Family CHRYSOMELIDAE

Pachybrachys mendicus Weise

Several specimens swept from herbage on the plateau above Uvero Beach, August 11-31, 1944.

Cryptocephalus multiguttatus Suffrian

The writer has numerous specimens in his collection dated April, 1935; March 3, June 29, July 20, and August 11-31, 1944, swept from weeds at Sardinera and Uvero Beaches and also on the plateau.

Nodonota wolcotti Bryant

Wolcott 1941: 100 reports this species on weeds. The writer has specimens swept from weeds at Sardinera Beach, March 6 and April 7, 1944.

Hermaeophaga cylindrica Weise

Reported by Wolcott 1941: 101 (Acc. No. 47-40).

Longitarus sp.
Det. H. S. Barber
Specimens taken at light, Sardinera Beach, April 7, 1944.

Aphthona compressa Suffrian
Adults very common, feeding on the leaves of *Stigmaphylon lingulatum* on the plateau, March 7 and July 20, 1944.

Megistops lituratus Olivier
Martorell collected specimens on *Clusia rosea,* April 2, 1940 (Acc. No. 311–40).

Chalepus sanguinicolis Linnaeus
One specimen swept from weeds, Sardinera Beach, July 20, 1944.

Family ANTHRIBIDAE

Toxotropis sp.
Det. L. L. Buchanan
A single specimen swept from vegetation, Sardinera Beach, August 11–31, 1944.

Family CURCULIONIDAE

Cylas formicarius Fabricius
One specimen at light, Sardinera Beach, April 5, 1944.

Artipus monae Wolcott
Described from Mona by Wolcott 1941: 102–103 from 15 specimens taken on August 8, 1939 on casuarina foliage and eggplant leaves. The writer has numerous specimens swept from mixed vegetation at Sardinera and Uvero Beaches, March 4–6, April 4–7, July 21, and August 11–31, 1944. Martorell observed adults feeding on the leaves of *Amyris elemifera* on April 6, 1944 (Acc. No. 37–44). Specimens in the collection of the College of Agriculture, Mayaguez, Puerto Rico, collected on the island by the author in April, 1935 and determined as *Artipus* sp. by L. L. Buchanan, are included under this species.

Diaprepes abbreviatus Linnaeus
Wolcott 1941: 103 reports adults feeding on the young leaves of *Terminalia Catappa* at Sardinera Beach, April 4, 1940.

Lachnopus kofresi Wolcott
Wolcott 1941: 104 described this species from 22 specimens taken on cultivated eggplants at Rancho Grande, August 8, 1939. The writer has

numerous specimens swept from vegetation at various localities on April 4–7, June 29, July 19 and 21, and August 11–31, 1944.

Apodrosus argentatus Wolcott

Wolcott 1941: 104 reports specimens taken from shoots of *Colubrina colubrina* at Sardinera Beach, April 1, 1940.

Anthonomus sp.

Several specimens swept from vegetation at Uvero Beach, March 7, 1944.

Pseudomopsis sp.

Det. L. L. Buchanan

One specimen swept from vegetation, Sardinera Beach, June 29, 1944.

Family PLATYPOIDAE

Platypus rugulosus Chapuis

One specimen at light, Sardinera Beach, March 7, 1944.

Family SCOLYTIDAE

Xyleborus confusus Eichoff

Det. W. H. Anderson

Adults at light, Sardinera Beach, April 7, and August 11–31, 1944.

Order LEPIDOPTERA

Family EUCHROMIIDAE

Eunomia rubripunctata Butler

Wolcott 1941: 125 reports adults at light, Sardinera Beach, March 30, 1940.

Family ARCTIIDAE

Ammalo insulata Walker

Adults reported by Wolcott 1941: 125 at light at the Lighthouse, April 1, 1940.

Calidota strigosa Walker

Reported by Wolcott 1941: 125 as abundant at light, Sardinera Beach and the Lighthouse, March 30, 1940. Adults collected in large numbers at light at Sardinera Beach, March 3–7 and April 4–7, 1944.

Family PERICOPIDAE

Composia sybaris Cramer

Wolcott 1941: 125 reports this species at light at Sardinera Beach, March

29–30, 1940. The writer secured numerous adults from the flowers of *Pisonia albida* at Uvero Beach, April 4–7, 1944.

Family NOCTUIDAE

Feltia subterranea Fabricius

Wolcott 1941: 126 reports the larvae of this species (as *F. annexa* Treitschke) on weeds at Sardinera, August 6, 1939. Numerous adults collected at light, Sardinera Beach, April 4–7 and August 11–31, 1944.

Catabena esula Druce

Reported by Wolcott 1941: 126 as common at light, Sardinera Beach and the Lighthouse, March 30 and April 1, 1940. The writer collected several adults at light, Camp Cofresí, April 4, 1944.

Micrathetis triplex Walker

Det. W. T. M. Forbes

A single adult taken at light, Sardinera Beach, April 4–7, 1944.

Eutelia piratica Schaus

Det. W. T. M. Forbes

One adult specimen collected at light, Sardinera Beach, April 4–7, 1944.

Mocis latipes Guenée

Det. W. T. M. Forbes

Adults collected at light, Sardinera Beach, August 11–31, 1944.

Mocis megas Guenée

Det. W. T. M. Forbes

Adults common at light, Sardinera Beach, August 11–31, 1944.

Plusia oo Fabricius

Det. W. T. M. Forbes

A single adult taken at light, Sardinera Beach, August 11–31, 1944.

Melipotis contorta Guenée

Det. W. T. M. Forbes

Several adults taken at light, Sardinera Beach, March 4, April 4–7, and June 29, 1944.

Melipotis famelica Guenée

Det. W. T. M. Forbes

Adults taken at light, Sardinera Beach, April 4–7 and August 11–31, 1944.

Melipotis januaris Guenée

Det. W. T. M. Forbes

Several adults collected at light, Sardinera Beach, April 4–7, 1944.

Melipotis fasciolaris Hübner

Det. W. T. M. Forbes

A single adult specimen taken at light, Sardinera Beach, April 4–7, 1944.

Hypenula complectalis Grote

Det. W. T. M. Forbes

Adults common at light, Sardinera Beach, April 4–7, June 29 and July 20, 1944.

Pseudohemiceras krugii Möschler

Wolcott 1941: 127 reports caterpillars of this species boring in the twigs of *Tabebuia lucida* and *Tabebuia heterophylla* on the plateau, April 1, 1940.

Glympis (Aluaca) eubolialis Walker

Det. W. T. M. Forbes

A single adult taken at light, Sardinera Beach, March 4, 1944.

Bendis gurda Guenée

Det. W. T. M. Forbes

Several specimens collected at light, Sardinera Beach, March 4, April 4–7, and June 29, 1944.

This species was previously recorded only from St. Thomas, Virgin Islands. According to Schaus 1940: 265 this species was unknown.

Azeta repugnalis Hübner

Det. W. T. M. Forbes

A single adult specimen collected at light, Sardinera Beach, April 4, 1944.

Epidromia pyraliformis

Det. W. T. M. Forbes

Adults taken at light, Sardinera Beach, June 21 and July 22, 1944.

Bleptina atymnusalis Walker

Det. W. T. M. Forbes

One specimen at light, Sardinera Beach, August 11–31, 1944.

Bleptina acastusalis Walker

Det. W. T. M. Forbes

Two specimens taken at light, Sardinera Beach, March 4, 1944.

Family NOTODONTIDAE

Nystalea ebalea Cramer

Det. W. T. M. Forbes

One specimen taken at light, Sardinera Beach, March 4, 1944.

Family SPHINGIDAE

Phlegethontius sextus jamaicensis Butler

Adults reported at light at the Lighthouse, April 1, 1940 by Wolcott 1941: 128.

Pseudosphinx tetrio Linnaeus

First reported from Mona by Leonard 1933: 135. Wolcott 1941: 129 reports one adult at light, the Lighthouse, and larvae on *Plumiera obtusa*, April 1, 1940. The writer has several adults taken at light at Sardinera Beach, March 4 and April 4–7, 1944. He also found practically all the *Plumiera* bushes on the plateau defoliated by the larvae.

Erinnyis ello Linnaeus

A single adult apecimen collected at light, Sardinera Beach, June 29, 1944.

Cautethia noctuiformis Walker

Wolcott 1941: 129 reports this species at light, Camp Cofresí, August 5, 1939.

Pachylia ficus Linnaeus

A single adult collected at light, Sardinera Beach, March 4, 1944.

Celerio lineata lineata Fabricius

Wolcott 1941: 129 reports specimens taken at light, Sardinera Beach, April 1, 1940.

Aëllopos tantalus Linnaeus var. **zonata** Drury

Martorell collected an adult on flowers of *Moringa moringa* at Sardinera Beach, April 1, 1940 (Acc. No. 315–40).

Family GEOMETRIDAE

Almodes terraria Guenée

Det. W. T. M. Forbes

Numerous specimens collected at light, Sardinera Beach, June 29 and July 20, 1944.

The description of the following new species was prepared by Dr. W. T. M. Forbes, Cornell University, who kindly gave his permission to include it with this report. The species should be credited to him.

Ptychopoda monata Forbes, n. sp.

General structures normal for the genus. Hind tibia much shorter than middle one, very thin and flimsy, but hollow and containing a large hair-pencil; femur linear; tarsus of five rounded segments, the first wider than tibia, then regularly decreasing; female hind tibia normal, with end spurs

only. Fore wing with accessory cell short and very slender, R_{2-4} and R_5 connate from its lower angle, R_1 also from its apex, but a little separated; R_4 apparently absent. Hind wing rather trapezoidal, sharply bent rather above M_3, the margin nearly erect above, but strongly oblique below, so that inner margin is only a little longer than part of outer margin below the bend. R and M_1 strongly stalked; male with a groove on under side along outer half of inner margin and around anal angle, filled with large spatulate scales attached close to inner margin.

Luteous. Face and palpi blackish, occiput with a slight transverse fuscous shade; legs shaded with fuscous, the fore legs mostly fuscous with contrasting luteous front tibia. Fore wing luteous, the outer third sometimes shaded with light fuscous or pale reddish brown, leaving a vague pale subterminal shade. Antemedial line heavy, black, excurved below costa, and toothed out on anal, incurved across submedian area and slanting in to inner margin; postmedial line heavy, strongly excurved opposite cell, a little incurved toward costa, and deeply incurved in a single sweep on lower half, slanting out again to inner margin. Discal dot a small oblique bar on lower part of discocellular. Medial area on lower half of wing often more or less shaded with black, sometimes almost solidly filled with black; the costal part sometimes shaded with red-brown about the discal bar. A series of small black terminal dots. Hind wing gray, with dark gray discal dot and a vague blackish median band running from it to middle of inner margin, sometimes reduced to a small triangular patch at inner margin; terminal dots as on fore wing. Abdomen shaded with red-brown above, with a few black scales. Expanse 11–12 mm.

Mona Island; a good series collected by J. A. Ramos in April 4–7, 1944; J. A. Ferrer, July 20, 1944; and L. F. Martorell in August, 1939. None of the specimens is in good condition, suggesting the species may be abnormally slow to die in the cyanide. Holotype, April 4–7, 1944 (Ramos) in the collection of the College of Agriculture, University of Puerto Rico, Mayaguez, Puerto Rico; paratypes in that collection and also the collection of Cornell University.

In the present state of confusion of the Sterrhinae it is not possible to be quite sure this species is not already described; but it is not represented in the National Museum, which is well supplied with West Indian material, nor in the Cornell University material from Puerto Rico and St. Croix. It should be distinguished from all the *Ptychopodas* known to me by the contrasting ordinary lines.

Racheospila sanctae-crucis Prout

Det. W. T. M. Forbes

Numerous adults taken at light, Sardinera Beach, June 29, 1944.

Racheospila cupedinaria Grote

Det. W. T. M. Forbes

A single specimen taken at light, Sardinera Beach, June 29, 1944.

Eucrotis sp.

Det. W. T. M. Forbes

Two specimens collected at light, Sardinera Beach, March 4, 1944.

Numia terebintharia Guenée

Det. W. T. M. Forbes

Several specimens taken at light, Sardinera Beach, April 4–7, July 20, and August 11–31, 1944.

Drepanodes infensata Guenée

Det. W. T. M. Forbes

Several specimens collected at light, Sardinera Beach, April 4–7 and July 20, 1944.

Family PYRALIDIDAE

Samea multuplicalis Guenée

Det. W. T. M. Forbes

Several specimens taken at light, Sardinera Beach, April 4–7, 1944.

Pilocrocis lauralis Walker

Wolcott 1941: 130 reports adults of this species at light, Camp Cofresí, August 7, 1939. The author has several adults also collected at light at the same locality, March 4, 1944.

Mesocondyla concordalis Hübner

Wolcott 1941: 130 records the larvae of this species on the leaves of *Tabebuia heterophylla* and *Tabebuia lucida* on the plateau, March 30, 1940. The writer has numerous adults of the pale variety (Det. W. T. M. Forbes) collected at light, Sardinera Beach, April 4–7 and August 11–31, 1944.

Dichogama amabilis Möschler

Adults reported at light, Camp Cofresí, August 7, 1939 and Sardinera Beach, April 1, 1940 by Wolcott 1941: 130. The writer collected several specimens at light at the same place on April 4–7, 1944.

Dichogama fernaldi Möschler

Det. W. T. M. Forbes

A single adult specimen taken at light, Sardinera Beach, June 29, 1944.

Dichogama redtenbacheri Lederer

Wolcott 1941: 131 reports a single adult collected at light, Sardinera Beach, March 30, 1940. The author collected numerous adults also at light at the same locality on April 4–7, 1944.

Lamprosema inabsconsalis Möschler

Det. W. T. M. Forbes

A single specimen at light, Sardinera Beach, April 4, 1944.

Margaronia costata Fabricius

Wolcott 1941: 131 reports adults at light, Camp Cofresí, August 6–7, 1939, and at Sardinera Beach, April 1, 1940. The writer has adults collected also at light, Sardinera Beach, April 4–7 and June 29, 1944. He found the larvae on the leaves of *Rawolfia nitida* at Sardinera, April 5, 1944.

Hellula phidilealis Walker

Det. W. T. M. Forbes

Numerous specimens taken at light, Sardinera Beach, March 4, April 4–7, and July 20, 1944.

Crocidophora algarrobalis Schaus

Det. W. T. M. Forbes

A single adult specimen collected at light, Sardinera Beach, July 20, 1944.

Psara phaeopteralis Guenée

Det. W. T. M. Forbes

Two specimens at light, Sardinera Beach, June 29, 1944.

Loxostege similalis Guenée

Det. W. T. M. Forbes

Many specimens taken at light, Sardinera Beach, July 20, 1944.

Crambus santiagellus Schaus

Det. W. T. M. Forbes

One specimen at light, Sardinera Beach, April 4, 1944.

Crambus fissiradiellus Walker

Det. W. T. M. Forbes

Two adults collected at light, Sardinera Beach, April 4, 1944.

Jocara sp.

Larvae attacking the leaves of *Conocarpus erecta*, south of Uvero Beach, April 5, 1944.

Scirpophaga longicornis Möschler

Reported at light at Sardinera Beach, August 5, 1939 by Wolcott 1941: 132.

Diatraea saccharalis Fabricius

Wolcott 1936: 475 reports the larvae on sugar cane without definite

locality or date. Later (1941: 132) he reports one adult at light at Sardinera Beach, April 1, 1940.

Elasmopalpus lignosellus Zeller
Det. W. T. M. Forbes
One adult specimen at light, Sardinera Beach, April 4, 1944.

Ephestiodes sp.
Det. W. T. M. Forbes
Several specimens taken at light, Sardinera Beach, July 20, 1944.

Family PTEROPHORIDAE

Trichoptilus defectalis Walker
Det. W. T. M. Forbes
One specimen taken at light, Sardinera Beach, June 29, 1944.

Family COSSIDAE

Psychonoctua personalis Grote
Wolcott 1941: 135 reports one adult at light, Camp Cofresí, August 6, 1939. Martorell and the writer found larvae boring in the trunk of *Coccolobis uvifera* at Uvero Beach, April 6, 1944.

Family GELECHIIDAE

Aristotelia diolcella Forbes
Det. W. T. M. Forbes
Several specimens collected at light, Sardinera Beach, March 4, 1944.

Stegasta capitella Fabricius
Det. W. T. M. Forbes
Specimens collected at light, Sardinera Beach, March 4, 1944.

Pectinophora gossypiella Saunders
Wolcott 1941: 136 reports a heavy infestation by the larvae of this species on wild cotton at Rancho Grande and Uvero Beach, August 5, 1939. During their visit to the island on April 4-7, 1944, Wolcott, Martorell, and the writer examined several plants of wild cotton at Uvero Beach and full-sized larvae were noted by them. Although only a few bolls were found to be attacked, it was presumed that the infection was general and that every plant was infested.

Family ETHMIIDAE

Ethmia notatella Walker
Wolcott 1941: 136 reports this species abundant at light at Camp Cofresí, August 6, 1939 and at Sardinera Beach and the Lighthouse, April

1, 1940. The writer found the species very abundant at light at Sardinera Beach, April 4–7, 1944. He has also numerous adults collected at light at that locality on March 4, 1944.

Family PSYCHIDAE

Oiketicus kirbyi Guilding

Wolcott 1941: 137 reports this bagworm on casuarinas at Sardinera Beach, August 5, 1939. The writer also noted the insect on the same host at the same locality and on *Pisonia albida* at Uvero Beach, April 7, 1944.

Family TINEIDAE

Tineola uterella Walsingham

Wolcott 1941: 137 reports the larvae on the walls of houses at Sardinera Beach, April 1, 1940. The writer also observed them abundant in houses at the same locality on April 4–7, 1944.

Family NEPTICULIDAE

Nepticula gossypii Forbes

Collected by Wolcott on wild cotton at Uvero Beach on September, 1944 (personal correspondence).

Family DANAIDAE

Danaus plexippus plexippus Linnaeus

One male collected on the plateau above Sardinera Beach, July 20, 1944.

Family NYMPHALIDAE

Heliconius charithonius charithonius Linnaeus

Wolcott 1941: 122 reports specimens flying in shaded places near the cliff, Sardinera Beach, August 7, 1939. The writer has several specimens collected at Sardinera Beach, March 5, and July 19–22, 1944, when the species was observed to be rather common.

Dione vanillae insularis Maynard

Recorded by Wolcott 1941: 122 at Sardinera Beach, April 1, 1940. Common at Sardinera and Uvero Beaches and on the plateau on April 4–7, June 29 and July 17–22, 1944, when numerous specimens were collected. Larvae taken at Uvero on *Corchorus hirsutus*, July 19, were bred to adults.

Junonia evarete zonalis C. and R. Felder

One specimen taken on the plateau, July 20, 1944.

Junonia evarete genoveva Cramer

Several specimens taken on the plateau, July 20, 1944.

Hypolimnas misippus Linnaeus

Wolcott (in correspondence) collected this species on September 1944.

Eunica monima Cramer

Wolcott 1941: 123 reports this species from Sardinera Beach, March 29, 1940.

Hamadryas ferox diasia Fruhstorfer

Det. W. P. Comstock

Four specimens collected at Sardinera Beach, August 11–31, 1944.

Family LYCAENIDAE

Hemiargus ammon noëli Comstock & Huntington

Det. W. P. Comstock

Comstock and Huntington 1941: 100 recorded a male of this Hispaniolan species captured on Mona Island, February 21–26, 1914 by F. E. Lutz. The writer has numerous specimens taken at Uvero Beach and on the plateau on the following dates: April 4–7 and July 29, 1944. Specimens taken at Sardinera Beach on April 1, 1940 and listed by Wolcott 1941: 123 as *Hemiargus* sp. near *zachcina* B. and D. undoubtedly belong to this species.

Family PIERIDAE

Phoebis (Phoebis) sennae sennae Linnaeus

Few adults were seen flying near the cliff at Sardinera Beach, April 4–7, 1944.

Eurema (Eurema) palmira palmira Poey

Det. W. P. Comstock

One specimen on the plateau, July 20, 1944.

Eurema (Pyrisitia) lisa euterpe Ménétriés

Det. W. P. Comstock

Two males, one white and one yellow female on the plateau, July 20, 1944.

Appias (Glutophrissa) drusilla boydi Comstock

Det. W. P. Comstock

Comstock 1944: 527 mentioned Mona Island in the distribution of this species. The writer has the following specimens in his collection, taken near the cliff at Sardinera Beach: 2 males, March 5, and another on June 29, and 1 female, April 4–7, 1944. Comstock's determination of the female specimen is accompanied by the following remark: "This is a very lightly marked female such as occurring in Hispaniola".

Ascia monuste eubotea Latreille

Det. W. P. Comstock

Two males and one female at Sardinera Beach, June 29, 1944. Comstock accompanies his determination of the female specimen with the remark: "This is a dark female like many from Hispaniola".

In following Comstock's (1944: 529) interpretation of the distribution of the forms of this species, the writer includes Wolcott's record of *monuste* from Mona Island ("attacking onions when normal host was weeded out," 1943: 123) under this form.

Family HESPERIIDAE

Urbanus proteus Linnaeus

Wolcott 1941: 124 recorded adults abundant on flowers of *Moringa moringa* and *Pisonia albida* at Sardinera Beach, April 1, 1940.

Urbanus dorantes cramptoni Comstock

Det. W. P. Comstock.

Comstock 1944: 546–547 designed 3 specimens from Mona Island as paratypes for his description of **cramptoni**: 2 males and 1 female, February 21–26, 1914. The writer has in his collection 2 specimens collected at Sardinera Beach, March 5 and April 7, 1944.

Pyrgus syrichtus Fabricius

Recorded by Wolcott 1941: 124 at Sardinera on August 8, 1939 and March 30, 1940. Four specimens in the author's collection (Det. W. P. Comstock) were collected on the plateau, August 11–31, 1944.

Ephyriades arcas Drury

Det. W. P. Comstock

One specimen collected on the plateau, July 21, 1944.

Wallengrenia otho mutchleri Watson

Wolcott 1942: 124 recorded specimens taken at Sardinera Beach, August 8, 1939 and March 30, 1940.

Lerodea tripuncta Herrich-Schäffer

Wolcott 1941: 124 reports this species at Sardinera Beach, August 7 1939. The writer has several specimens (Det. W. P. Comstock) taken at Sardinera Beach, August 11–31, 1944.

Panoquina nyctelia Latreille

On weeds at Sardinera Beach, August 6, 1939 (Wolcott 1941: 124).

Order DIPTERA

Family CULICIDAE

Aëdes aegypti Linnaeus

Curran 1928: 10 reports four males collected on Mona Island by F. E.

Lutz, February 21–26, 1914. The writer found this mosquito common and troublesome at Sardinera Beach, April 4–7, 1944.

Culex fatigans Wiedemann

This species was found by the writer extremely abundant and troublesome at Sardinera Beach, April 4–7, 1944.

Family CECIDOMYIDAE

Cecidomyia coccolobae Cook

Wolcott 1941: 112 reports this species as making small cone-shaped galls on the leaves of *Coccolobis uvifera*, August 9, 1939.

Family STRATIOMYIDAE

Neorondania chalybea Wiedemann

Wolcott 1941: 112 records this species as abundant in houses and latrines at Camp Cofresí, August 8, 1939 and at the Lighthouse, April 1, 1940.

Nemoteles monensis Curran

Described by Curran 1928: 16 from a single female taken on Mona Island by F. E. Lutz on February 21–26, 1914.

Family TABANIDAE

Tabanus caribaeorum Bequaert

This species was described from Grand Cayman and Mona Island by Bequaert 1940: 323–326. The two paratypes from Mona, a male and a female, were collected in 1940 by L. F. Martorell.

Tabanus stigma Fabricius

Wolcott 1941: 113 reports this species collected at Camp Cofresí, August 6, 1939.

Family BOMBYLIIDAE

Hyperalonia cerberus Fabricius

Curran 1928: 19 reports specimens taken by F. E. Lutz on February 21–26, 1914 and Wolcott 1941: 113 reports specimens collected at Playa de Pájaros, Uvero Beach, and Camp Cofresí, August 7, 1939. The writer has several specimens taken at Sardinera Beach and on the plateau, August 11–31, 1944.

Spongostylum sp. near **pluto** Wiedemann

Wolcott 1941: 113 reports specimens taken at Playa de Pájaros, August 8, 1939.

Heterostylum ferrugineus Fabricius

Wolcott 1941: 114 reports one specimen taken in a cave, August 8, 1939. The writer collected one specimen on weeds at Sardinera Beach, April 6, 1944.

Exoprosopa sp. near **dodrans** Osten Sacken

Wolcott 1941: 114 reports specimens taken on weeds, Playa de Pájaros, August 8, 1939.

Villa lateralis Say

Specimens taken by F. E. Lutz on February 21–26, 1914 are reported by Curran 1928: 20.

Villa gorgon Fabricius

Curran 1928: 21 reports this species from specimens collected on February 21–26, 1914 by F. E. Lutz. Wolcott 1941: 114 reports additional specimens collected on August 8, 1939 and April 1, 1940. The writer found the species rather common at Sardinera and Uvero Beaches and on the plateau on April 4–7, 1944. He has other specimens collected on August 11–31, 1944.

Family ASILIDAE

Ommatius marginellus Fabricius

Recorded by Wolcott 1941: 114 on weeds at Rancho Grande, August 7, 1939.

Leptogaster cubensis Bigot

Known from Mona only by two specimens collected on February 21-26, 1914 by F. E. Lutz and reported by Curran 1928: 22.

Plesioma sp. near **indecora** Leow

Reported by Wolcott 1941: 114 on weeds at Camp Cofresí, August 6, 1939.

Family THEREVIDAE

Psilocephala monensis Curran

Described by Curran 1926:2 from a single specimen collected by F. E. Lutz on February 21–26, 1914.

Psilocephala vexans Curran

Originally described by Curran 1926: 2 from a series of specimens from Puerto Rico and other West Indian Islands. Two of the paratypes were taken at Mona on February 21–26, 1914.

Family DOLICHOPODIDAE

Thrypticus violaceus Van Duzee

Van Duzee (in Curran 1928: 30) reports specimens of this species from Mona taken on February 21–26, 1914.

Sciapus albiciliatus Van Duzee

Originally described by Van Duzee 1927: 9–10 from specimens from

Puerto Rico, Virgin Islands and one from Mona collected by F. E. Lutz, February 21–26, 1914.

Psilopus sp. near **insularis** Aldrich

Det. C. T. Greene

Martorell collected specimens on weeds at Sardinera Beach, April 1, 1940 (Acc. No. 292–40).

Family SYRPHIDAE

Baccha conformis Leow

Wolcott 1941: 115 reports specimens taken at Sardinera Beach, August 7, 1939 and on the plateau, April 1, 1940.

Baccha cylindrica Fabricius

Curran 1928: 26 lists specimens collected on the island by F. E. Lutz on February 21–26, 1914. The writer has specimens taken at Sardinera Beach on August 11–31, 1944.

Baccha fasciata Roeder

Wolcott 1941: 115 reports this species taken on weeds at Sardinera Beach, April 1, 1940.

Allograpta fuscisquama Curran

Curran 1927: 5 included a male taken on Mona Island by F. E. Lutz on February 21–26, 1914, as a paratype in his description of this species.

Allograpta limbata Fabricius

Wolcott 1941: 115 reports this species as collected at Sardinera Beach, March 30, 1940.

Volucella horvathi Szilady

Wolcott 1941: 115 records this species flying in the shade of trees at Sardinera Beach and Playa de Pájaros, August 8, 1939.

Family PHORIDAE

Megaselida scalaris Leow

Curran 1928: 43 reports numerous specimens from Mona Island collected on February 21–26, 1914.

Syneura cocciphila Coquillett

Wolcott obtained several adults from *Icerya purchasi*, April 6, 1944 (Acc. No. 62–44).

Family CHLOROPIDAE

Prohippelates pallidus Leow

This Cuban species is known from Mona by a single specimen collected

on the island on February 21–26, 1914 by F. E. Lutz and reported by Curran 1928: 45.

Hippelates dorsatus Williston

Curran 1928: 46 reports three specimens collected on Mona, February 21–26, 1914.

Hippelates tener Coquillett

One specimen taken on the island on February 21–26, 1914 by F. E. Lutz is reported by Curran 1928: 47.

Hippelates convexus Loew

Curran 1928: 49 reports specimens collected on February 21–26, 1914.

Hippelates flavipes Loew

Curran reports specimens collected by F. E. Lutz on February 21–26, 1914.

Hippelates lutzi Curran

Described from Mona Island by Curran 1926: 5 from specimens taken there by F. E. Lutz on February 21–26, 1914.

Hippelates bicolor Coquillett

Curran 1928: 49 reports specimens collected on the island on February 21–26, 1914 by F. E. Lutz.

Hippelates collusor Curran

A female collected on Mona Island by F. E. Lutz on February 21–26, 1914 was designed by Curran 1926: 4 as a paratype in his description of this species.

Hippelates pusio Loew

Curran 1928: 49 reports specimens collected on the island on February 21–26, 1914.

Hippelates apicata Malloch

Curran 1928: 50 lists specimens from Mona Island collected on February 21–26, 1914.

Botanobia limitata Becker

Specimens collected in Mona Island on February 21–26, 1914 are reported by Curran 1928: 53.

Botanobia sicatrix Curran

Described from Mona Island by Curran 1926: 8 from 17 specimens collected on February 21–26, 1914.

Botanobia mona Curran

Curran 1926: 9 described this species from Mona Island from specimens collected there on February 21–26, 1914.

Botanobia mars Curran

Curran 1926: 10 designed two females collected on Mona Island, February 21–26, 1914, as paratypes in his description of this species.

Botanobia tripunctata Curran

The original description of this species by Curran 1926: 10 is based on three specimens collected on Mona Island on February 21–26, 1914.

Botanobia varipalpus Curran

Another species described by Curran 1926: 12 from specimens collected on Mona Island on February 21–26, 1914.

Family EPHYDRIDAE

Ceropsilopa coquilletti Cresson

A single specimen taken on the island on February 21–26, 1914 is listed by Curran 1928: 61.

Plagiops aciculata Loew

Listed by Curran 1928: 62 as collected on the island on February 21–26, 1914.

Discocerina obscurella Fallen

Curran 1928: 63 reports a single specimen from Mona Island, collected on February 21–26, 1914.

Family AGROMYZIDAE

Agromyza aeneiventris Fallen?

Wolcott 1941: 121 reports this species on tender leaves of *Coccolobis laurifolia* (Acc. No. 43–40).

Cryptochaetum iceryae Williston

Adults from a shipment of parasitized cottony cushion scales from California released in the island in 1940 (Wolcott 1941: 121).

Family OCHTHIPHILIDAE

Acrometopia maculata Coquillett

Curran 1928: 66 reports seven specimens taken on the island on February 21–26, 1914.

Family MICHILIDAE

Michiella lacteipennis Loew
Curran 1928: 67 lists one specimen taken in the island on February 21–26, 1914.

Pholeomyia indecora Loew
A single specimen collected in the island on February 21–26, 1914 is reported by Curran 1928: 68.

Family TRYPANEIDAE

Tetraeuaresta obscuriventris Loew
Wolcott 1941: 120 reports one specimen collected on weeds at Sardinera Beach, April 1, 1940.

Family SEPSIDAE

Sepsis pusio Schiner
Curran 1928: 76 reports specimens collected in the island on February 21–26, 1914.

Family OTITIDAE

Euxesta stigmatias Loew
Specimens collected in the island on February 21–26, 1914 are reported by Curran 1928: 78.

Euxesta abdominalis Loew
Curran 1928: 79 reports specimens collected in Mona on February 21–26, 1914.

Euxesta annonae Fabricius
Curran 1928: 79 reports specimens taken on the island on February 21–26, 1914.

Notogramma stigma Fabricius
Specimens collected in the island on February 21–26, 1914 are reported by Curran 1928: 79.

Family SAPROMYZIDAE

Carpolonchaea pendula Bezzi
Wolcott 1941: 118 reports this species taken on weeds at Camp Cofresí, August 5, 1939 and at Sardinera Beach, April 1, 1940.

Camptoprosopella diversa Curran
Curran 1928: 82 lists one specimen taken on Mona, February 21–26, 1914.

Neogriphoneura sordida Wiedemann

Two specimens collected on the island, February 21–26, 1914, are listed by Curran 1928: 82.

Minettia slossonae Coquillett

Curran 1928: 84 reports specimens collected on February 21–26, 1914.

Minettia mona Curran

Described by Curran 1926: 13–14 from 6 specimens from Mona Island, February 21–26, 1914, and 3 from Puerto Rico.

Family MUSCIDAE

Musca domestica Linnaeus

Wolcott 1941: 117 gives several records for the housefly from Mona on August 6, 1939; March 29 and April 5, 1940. The writer found the species very abundant in houses in April 4–7, 1944.

Family CALLIPHORIDAE

Cochliomyia macellaria Fabricius

First reported from the island by Curran 1928: 92, who lists specimens collected on February 21–26, 1914. Wolcott 1941: 117 reports that this fly is so abundant and troublesome on the island as to prevent drying of fish on the beach.

Cochliomyia laniaria Wiedemann

Curran 1928: 92 reports specimens taken on February 21–26, 1914. Martorell collected the species on flowers of *Colubrina colubrina* on the plateau, April 1, 1940 (Acc. No. 284–40).

Lucilia eximia Macquart

Martorell secured one specimen, determined as this species by D. G. Hall, at Sardinera Beach, March 30, 1940 (Acc. No. 277–40).

Family SARCOPHAGIDAE

Sarcophaga bakeri Aldrich

Curran 1928: 99 reports specimens collected on February 21–26, 1914.

Sarcophaga currani Hall

Wolcott 1941: 117 reports specimens taken at the Viejo Lirio cave, Playa de Pájaros, August 9, 1939.

Sarcophaga rapax Walker

Det. M. T. James

Specimens obtained by Wolcott from a dead adult of *Strataegus barbigerus* collected between Sardinera and Uvero Beaches, October 2, 1944 (Acc. No. 196–44).

Helicobia globulus Aldrich
Curran 1928: 100 lists specimens taken on February 21–26, 1914.

Helicobia helicis Townsend
Specimens taken in the island, February 21–26, 1914, are listed by Curran 1928: 101.

Sarcophagula occidusa Fabricius
Curran 1928: 101 reports specimens from Mona, February 21–26, 1914.

Harpagopyga diversipes Coquillett
Curran 1928: 102 lists one specimen from the island, February 21–26, 1914.

Sarothromyia femoralis Schiner
Wolcott 1941: 117 reports this species at light (Acc. No. 374–39).

Senotainia rubriventris Macquart
Curran 1928: 104 reports a single specimen from the island, February 21–26, 1914.

Family HIPPOBOSCIDAE

Olfersia spinifera Leach
Recorded by Wolcott 1941: 121 from man-o'-war bird, *Fregata magnificens rothschildi* Mathews, Sardinera Beach, August 6, 1939.

Order SIPHONAPTERA

Family HECTOPSYLLIDAE

Tunga penetrans Linnaeus
On man, Sardinera Beach, August 6, 1939 (Wolcott 1941: 122).

Family PULICIDAE

Ctenocephalides canis Curtis
Wolcott 1941: 122 reports this flea on dogs, Sardinera Beach, August 5, 1939.

Order HYMENOPTERA

Family ICHNEUMONIDAE

Trornatobia lateralis Cresson
Det. H. K. Townes
One specimen at Uvero Beach, August 11–31, 1944.

Family BRACONIDAE

Apanteles sp.
Det. C. F. W. Muesebeck
One specimen, Sardinera Beach, April 5, 1944.

Iphiaulax sp.

Martorell collected three specimens at Camp Cofresí, August 6, 1939 (Acc. No. 188–39). The writer has one specimen, determined by C. F. W. Muesebeck, taken on the plateau, July 21, 1944.

Trigonophasmus sp. nov.

Wolcott 1941 : 140 reports one specimen collected on the plateau, April 1, 1940.

Family CHALCIDIDAE

Brachymeria incerta Cresson

Wolcott 1941 : 147 records one specimen taken on the plateau, April 1, 1940.

Ceratomiscra debilis Cresson

Det. A. B. Gahan

One specimen on the plateau, August 11–31, 1944.

Spilochalcis flavopicta Cresson

Wolcott 1941: 147 reports one specimen collected at Camp Cofresí, August 7, 1939. The writer collected one specimen (Det. A. B. Gahan) at Sardinera Beach, April 5, 1944.

Spilochalcis homaledrae Wolcott

Martorell collected one specimen on the flowers of *Pisonia albida* on the plateau, April 2, 1940 (Acc. No. 308–40).

Family CALLIMOMIDAE

Megastigmus sp. nov.

Det. A. B. Gahan

One specimen on the plateau above Uvero Beach, August 11–31, 1944.

Family PTEROMALIDAE

Pachyneuron allograptae Ashmead

Wolcott 1941: 144 reports this species from Rancho Grande on syrphid fly puparia, March 31, and resting on watermelons, March 30, 1940.

Family EUPELMIDAE

Eupelmus sp. a.

Det. A. B. Gahan

One specimen, April 4; and 3 specimens, August 11–31, 1944.

Eupelmus sp. b.

Det. A. B. Gahan

One specimen, April 7, 1944.

Anastatus sp.

Det. A. B. Gahan

Reared by Wolcott from egg masses of *Callimantis antillarum* taken at Camp Cofresí, October 3, 1944 (Acc. No. 197–44).

Family EULOPHIDAE

Tetrastichus sp.

Det. A. B. Gahan

One specimen, Sardinera Beach, August 11–31, 1944.

Family SCELIONIDAE

Hoploteleia sp., "apparently new"

Det. C. F. W. Muesebeck

One specimen, Sardinera Beach, June 29, 1944.

Telenomus sp.

Det. A. B. Gahan

Specimens collected at Sardinera Beach, August 11–31, 1944.

Family DRYINIDAE

Gonatopus sp.

Det. C. F. W. Muesebeck

One specimen swept from weeds, Sardinera Beach, April 4, 1944.

Family FORMICIDAE

Dr. M. R. Smith, Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, kindly determined all the species of ants from Mona Island in the author's collection.

Platythyrea punctata F. Smith

A single worker collected in the shade at the base of the cliff, Sardinera Beach, August 11–31, 1944.

Ponera opaciceps Mayr

Collected at Sardinera Beach, August 11–31, 1944.

Odontomachus haematodes insularis Guerin

Wolcott 1941: 148 reports this species nesting in a rotten stump at Sardinera Beach, August 7, 1939 and at light on the same locality, April 1, 1940. The writer found a nest in a rotten wild papaya trunk near the cliff at Sardinera Beach, April 4, and has many specimens swept from weeds at the same place, April 2 and August 11–31, 1944.

Monomorium floricola Jerdon

Wolcott 1941: 149 reports this species nesting in a stump at Camp

Cofresí, August 5, 1939. The writer has numerous specimens taken at Sardinera Beach, March 6 and August 11–31, 1944.

Monomorium pharaonis Linnaeus

Many workers swept from vegetation, Uvero Beach, August 11–31, 1944.

Cardiocondyla emeryi Forel

Specimens collected at Sardinera Beach, August 11–31, 1944.

Cardiocondyla venustula Wheeler

Smith 1944: 38 reports specimens taken on Mona Island on February 21–26, 1914.

Solenopsis geminata Fabricius

Wolcott 1941: 149 reports this ant as abundant all over the island, August 5–7, 1939; and attending *Icerya purchasi* on casuarinas at Sardinera Beach, March 29, 1940. The writer observed the species attending *Coccus viridis* on *Rauwolfia nitida* at Sardinera Beach, April 5, 1944.

Pheidole moerens Wheeler

Numerous specimens collected under debris in a shaded place near the base of the cliff, Sardinera Beach, August 11–31, 1944.

Macromischa albispina subsp. **albipes** Mann

Described by Mann 1920: 424 from Mona Island as a variety of *M. albispina* Wheeler. It was later raised to subspecific rank by Wheeler 1931: 1–34. Smith 1937: 851 gives notes on this ant but does not give any records of new captures. The writer has specimens taken on the ground under the shade at the base of the cliff, Sardinera Beach, August 11–31, 1944.

Tetramorium guineense Fabricius

Many specimens swept from weeds, Sardinera and Uvero Beaches, April 5, 1944.

Wasmannia auropunctata Roger

Wolcott 1941: 149 records specimens on the ground, Camp Cofresí, August 5, 1939. The writer noted the species abundant on the young shoots of *Terminalia Catappa* at Sardinera Beach, April 5, 1944.

Dorymyrmex pyramicus var. **niger** Pergande

Wolcott 1941: 150 reports this species nesting in a stump at Camp Cofresí, August 5, 1939; and attending *Icerya purchasi* on casuarinas at Sardinera Beach, March 29, 1940. The writer found it common at Sardinera and Uvero Beaches, April 4–7, 1944. He has also numerous specimens swept from vegetation at the same localities, March 4, July 19, and August 11–31, 1944.

Trachymyrmex jamaicensis André

Nesting in the open ground at Los Cerezos on the plateau, July 21, and in shaded places near the cliff, Sardinera Beach, August 11–31, 1944.

Tapinoma melanocephalum Fabricius

Nesting in rotten stump of *Coccolobis laurifolia*, Sardinera Beach, April 5, 1944.

Prenolepis longicornis Latreille

Wolcott 1941: 150 records this species as abundant at Camp Cofresí, August 5–6, 1939.

Camponotus sp.

Nesting in a rotten stump of *Conocarpus erecta*, Uvero Beach, April 7, 1944.

Myrmelachista ramulorum subsp. **fortior** Wheeler

Wheeler 1934: 189–190 described the subspecies of this ant from 5 workers collected on Mona Island by F. E. Lutz on February 21–26, 1914, and 2 workers collected by him in Puerto Rico. Smith 1937: 873 discusses the species without giving any new records for Mona Island. The writer has numerous workers taken at Sardinera Beach, August 11–31, 1944.

Family BEMBECIDAE

Bicyrtes spinosa Fabricius

Wolcott 1941: 150 records a single specimen taken on weeds at Sardinera Beach, August 6, 1939. The writer has two specimens, determined by H. K. Townes, collected at Sardinera Beach, March 6 and July 19, 1944.

Stictia signata Linnaeus

Common all over the island (Wolcott 1941: 151). The writer has many specimens collected at Sardinera Beach, March 6, April 7 (attracted by dead bird), July 20, and August 11–31, 1944.

Family SPHECIDAE

Tachytes insularis Cresson

Wolcott 1941: 152 records specimens at the airfield, August 9, 1939 and also at Sardinera and on the plateau, April 1, 1940.

Tachytes sp.

Det. H. K. Townes

Four specimens taken at Uvero Beach and on the plateau, August 11–31, 1944.

Motes sp. a.

Det. H. K. Townes

A single specimen taken on the plateau above Uvero Beach, August 11–31, 1944. Townes' determination of this species is accompanied by the remark: "*Motes* sp. a. is like specimens in the National Museum determined as *Motes vinulentus* Cresson".

Motes sp. b.

Det. H. K. Townes

One specimen from the plateau, August 11–31, 1944. Townes remarks that: "This species is like specimens in the National Museum determined as *Motes trifasciatus* Smith".

Chlorion (Ammobia) singularis F. Smith

Wolcott 1941: 152 reports one specimen taken at Sardinera Beach, March 30, 1940.

Chlorion thomae Fabricius

Wolcott 1941: 152 reports this species at the airfield, August 8, 1939; and also abundant at the plateau, March 30, 1940. The writer has numerous specimens from Uvero Beach and the plateau, April 7, June 29, July 21, and August 11–31, 1944.

Trypoxylon sp.

Det. H. K. Townes

Numerous specimens taken on the plateau, August 11–31, 1944.

Family CRABRONIDAE

Crabro croesus Lepeletier

Listed by Wolcott 1936: 556 from Mona (Acc. No. 1308–13).

Family SCOLIIDAE

Elis haemorrhoidalis Fabricius

Wolcott 1941: 153 reports specimens taken on flowers of *Colubrina colubrina* and *Pisonia albida* at Sardinera Beach and on the plateau, March 30, 1940. The writer collected one specimen while sweeping on weeds at Uvero Beach, April 7, 1944.

Campsomeris atrata Fabricius

Recorded by Wolcott 1941: 154 at Sardinera Beach, August 7, 1939; and on flowers of *Moringa moringa*, *Pisonia albida*, and *Colubrina colubrina*, Sardinera Beach, March 30, 1940. The writer found the species abundant at Uvero Beach, April 5, 1944.

Campsomeris dorsata Fabricius

Wolcott 1941: 154 reports specimens on the ground at Sardinera Beach, August 6, 1939 and on flowers of *Moringa moringa*, March 30, 1940.

Family EUMENIDAE

Zethus rufinodus Latreille

Common on flowers of *Lantana* at Sardinera and Playa de Pájaros, August 6–8, 1939; and on the tender foliage of *Coccolobis laurifolia*, March 30, 1940 (Wolcott 1941: 156). The writer has specimens taken at Uvero and Sardinera Beaches, April 4 and July 20–21, 1944.

Family PSAMMOCHARIDAE

Cryptocheilus flammipennis Smith

Several specimens flying near the ground among weeds, Sardinera and Uvero Beaches, April 5–6, 1944.

Family VESPIDAE

Polistes crinitus Felton

Wolcott 1941: 155 records this wasp as abundant, nests on trees and other plants all over the island, August 5, 1939 and April 2, 1940. The writer found it rather scarce in April 4–7, 1944. He has one specimen dated August 11–31, 1944.

Polistes major Palisot de Beauvois

Nesting on sea-grape and casuarina trees, Playa de Pájaros and Sardinera Beach, August 8, 1939 (Wolcott 1941: 155). The writer noted a large nest on a *Lantana* bush at Sardinera Beach, April 6, 1944.

Mischocyttarus cubensis Saussure

Wolcott 1941: 156 reports specimens collected on weeds near Camp Cofresí, August 8, 1939. The author found a nest under a leaf of a tree at Sardinera Beach, April 4, 1944.

Pachodyneurus tibialis Saussure

Adults frequenting flowers of *Lantana* at Sardinera Beach and Playa de Pájaros, August 6, 1939; and of *Colubrina colubrina* at Sardinera Beach, March 30, 1940 (Wolcott 1941: 156). The writer has specimens, determined by H. K. Townes, from Sardinera Beach, July 21 and August 11–31, 1944.

Rygchium sp.

Det. H. K. Townes

One male specimen on the plateau, July 21, 1944.

Family HALICTIDAE

Agapostemon portoricensis Cockerell

Wolcott 1941: 156 lists specimens frequenting flowers of *Lantana* at Playa de Pájaros and Sardinera Beach, August 6–7, 1939.

Halictus sp.

Martorell collected specimens by sweeping on weeds at Sardinera Beach, April 1, 1940 (Acc. No. 291–40). The writer collected several specimens also from weeds at the same locality, April 5, 1944.

Family ANTHOPHORIDAE

Centris haemorrhoidalis Fabricius

Wolcott 1941: 157 reports specimens on the flowers of *Moringa moringa* and *Pisonia albida* at Sardinera Beach and on the plateau, March 31, 1940.

Centris lanipes Linnaeus

On weeds at Sardinera Beach, August 7, 1939 and on flowers of *Moringa moringa*, *Colubrina colubrina* and *Pisonia albida*, Sardinera Beach and the plateau, March 30, 1940 (Wolcott 1941: 157).

Centris versicolor Fabricius

Wolcott 1941: 157 reports adults abundant on the flowers of *Lantana* at Playa de Pájaros, August 8, 1939 and of *Moringa moringa*, Sardinera Beach and the plateau, April 3, 1940.

Anthophora krugii Cresson

Adults reported by Wolcott 1941: 157 in walls of cave at Playa de Pájaros, August 8, 1939 and frequenting the flowers of *Moringa moringa* and *Colubrina colubrina*, Sardinera Beach, March 30, 1940.

Family MEGACHILIDAE

Megachile n. sp.

Det. T. B. Mitchell

Martorell collected two specimens of this new *Megachile* on the flowers of *Moringa moringa* and *Pisonia albida* at Playa de Pájaros, August 8, 1939. These specimens were reported as *Megachile vitrasi* Pérez by Wolcott 1941: 157. The writer has a single specimen taken at Sardinera Beach, August 11-31, 1944. All this material was examined by Dr. T. B. Mitchell, who found it to represent an undescribed species. A specimen taken by Wolcott at Guánica, Puerto Rico, August 24, 1939 (Acc. No. 225–39) and kindly loaned by him, constitutes a fourth specimen of this new *Megachile*.

Family XYLOCOPIDAE

Xylocopa brasilianorum Linnaeus

Abundant all over the island, August 7, 1939 (Wolcott 1941: 158). The writer has specimens taken at Sardinera, March 3, 1944. He found a nest with several adult males and females in an old branch of *Ficus Stahlii* at Sardinera Beach, April 4, 1944.

Discussion and Analysis of the Insect Fauna

In the present work, a total of 526 species of insects is recorded from Mona Island. Of this number, 24 species, or 4.56 per cent, are endemic to the island; 27 species, or 5.11 per cent, are also known only from the Puerto Rican mainland; 53 species, or 10.07 per cent, although known from other West Indian islands or other regions, are not known from Puerto Rico itself; and 422 species, or 80.22 per cent, are widely ranging forms, occurring in some or in all of the West Indies, or in neighboring regions (Table I).

TABLE I

Order	No. of Families	Endemic species	In common with P. R.	Not known from P. R.	Of wide distribution	Total
1. *Thysanura*	1	0	0	0	1	1
2. *Collembola*	1	0	0	1	0	1
3. *Orthoptera*	8	3	1	0	24	28
4. *Dermaptera*	1	0	0	0	1	1
5. *Isoptera*	1	1	1	1	1	4
6. *Neuroptera*	3	0	1	3	4	8
7. *Odonata*	2	0	0	0	5	5
8. *Mallophaga*	1	0	0	0	1	1
9. *Thysanoptera*	1	0	0	0	1	1
10. *Homoptera*	16	3	2	2	56	63
11. *Hemiptera*	16	3	1	4	49	57
12. *Coleoptera*	36	5	7	16	95	123
13. *Lepidoptera*	20	1	5	9	73	88
14. *Diptera*	22	6	6	7	59	78
15. *Siphonaptera*	2	0	0	0	2	2
16. *Hymenoptera*	21	2	3	10	50	65
Totals	152	24	27	53	422	526
Percentage		4.56	5.11	10.07	80.22	

The Coleoptera is represented by 123 species of which 5 are endemic, 7 occur also only in Puerto Rico itself, and 16 are not known from the latter island, although they occur also in other of the West Indies.

The Diptera has 78 representatives in this report. Of these, 6 species are endemic to Mona Island, 6 occur also only in Puerto Rico, and 7 range throughout other West Indian islands but not in Puerto Rico itself.

The Hymenoptera is represented by 65 species of which 2 are endemic, 3 are shared with Puerto Rico only and 10 occur in other of the West Indies but not Puerto Rico itself.

In the Homoptera, 63 species are recorded from the island of which 3 are endemic, 2 occur also in Puerto Rico only and 2 are not known from Puerto Rico itself although they occur in other localities. The family Kinnaridae, until recently not known from Puerto Rico itself, is represented in Mona by a new genus and species.

The Hemiptera is represented by 57 species of which 3 are endemic, one is shared with Puerto Rico only, and 4 do not occur in the latter island itself.

A total of 88 species is recorded in the Lepidoptera. Of these, one new species is described from the island, 5 are shared with Puerto Rico only and 9 with other regions but not Puerto Rico itself.

The Orthoptera is represented by 28 species of which 3 are endemic forms, one is shared with Puerto Rico only, and the rest are widely distributed in the West Indies.

Of the remaining orders of insects represented, the Isoptera is the only one having an endemic species from the island.

The paucity of the insect fauna of Mona Island, as shown by the above analysis, is probably due not only to the small area of the island but also to the extremely arid condition and scant vegetation of the region. Its most interesting feature is undoubtedly the fact that the number of species in common with other regions but not known from Puerto Rico itself (53 species, or 10.07 per cent) is nearly two times greater than the number of species in common with that island (27 species, or 5.11 per cent). This could be interpreted in the sense that the island's insect fauna has less affinities with that of Puerto Rico itself than with that of the other Greater Antilles. Unfortunately, the lack of a better knowledge of the insect faunas of these islands, especially of Hispaniola, does not permit a more definite statement in this respect.

Summary

A total of 526 species of insects, representing 16 orders and 152 families, is recorded from Mona Island, with notes on their distribution, abundance, and host plants. Of this number of species, 197 were not previously known from the island. *Paradarnoides danforthi* n. sp. (Homoptera, Membracidae); *Paraprosoptropis* n. gen., *Paraprosoptropis monensis* n. sp. (Homoptera, Kinnaridae); *Flatoidinus pseudopunctatus* n. sp. (Homoptera,

Flatidae); *Ozophora octomaculata* n. sp. (Hemiptera, Lygaeidae); and *Ptychopoda monata* Forbes, n. sp. (Lepidoptera, Geometridae) are described. The insect fauna of Mona Island is analyzed and discussed.

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EXPLANATION OF PLATES

Plate I

1. *Paradarnoides danforthi* sp. nov.; lateral view. 2. Dorsal outline. 3. Frontal view of head. 4. Male genitalia. 5. *Paraprosoptropis monensis* sp. nov.; frontal view of head. 6. Lateral view of male genitalia. 7. Ventral view of female subgenital plate. 8. Dorsal view of head and thorax. 9. Tegmen.

Plate II

10. *Flatoidinus pseudopuctatatus* sp. nov.; dorsal view of head and thorax. 11. Frontal view of head. 12. Ventral view of female genitalia. 13. Ventral view of male genitalia. 14. *Melormenis antillarum* Kirkaldy; ventral view of male genitalia. 15. *Flatoidinus pseudopunctatus* sp. nov.; lateral view of male genitalia. 16. *Colpoptera flavifrons* Osborn; lateral view of male genitalia. 17. *Melormenis antillarum* Kirkaldy; lateral view of male genitalia. 18. *Petrusa marginata* Brunnich; male genitalia of dark form. 19. Male genitaliá of pale form. 20. *Ozophora octomaculata* sp. nov.; dorsal view.

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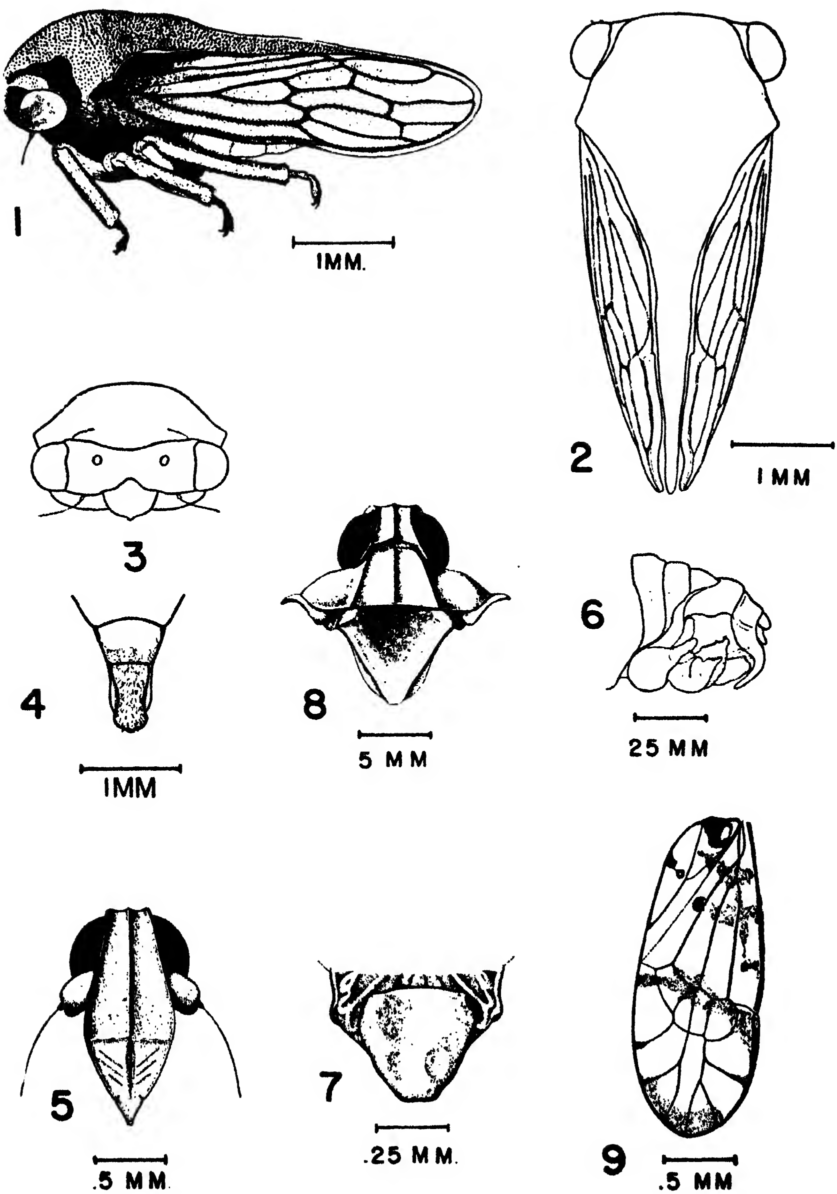
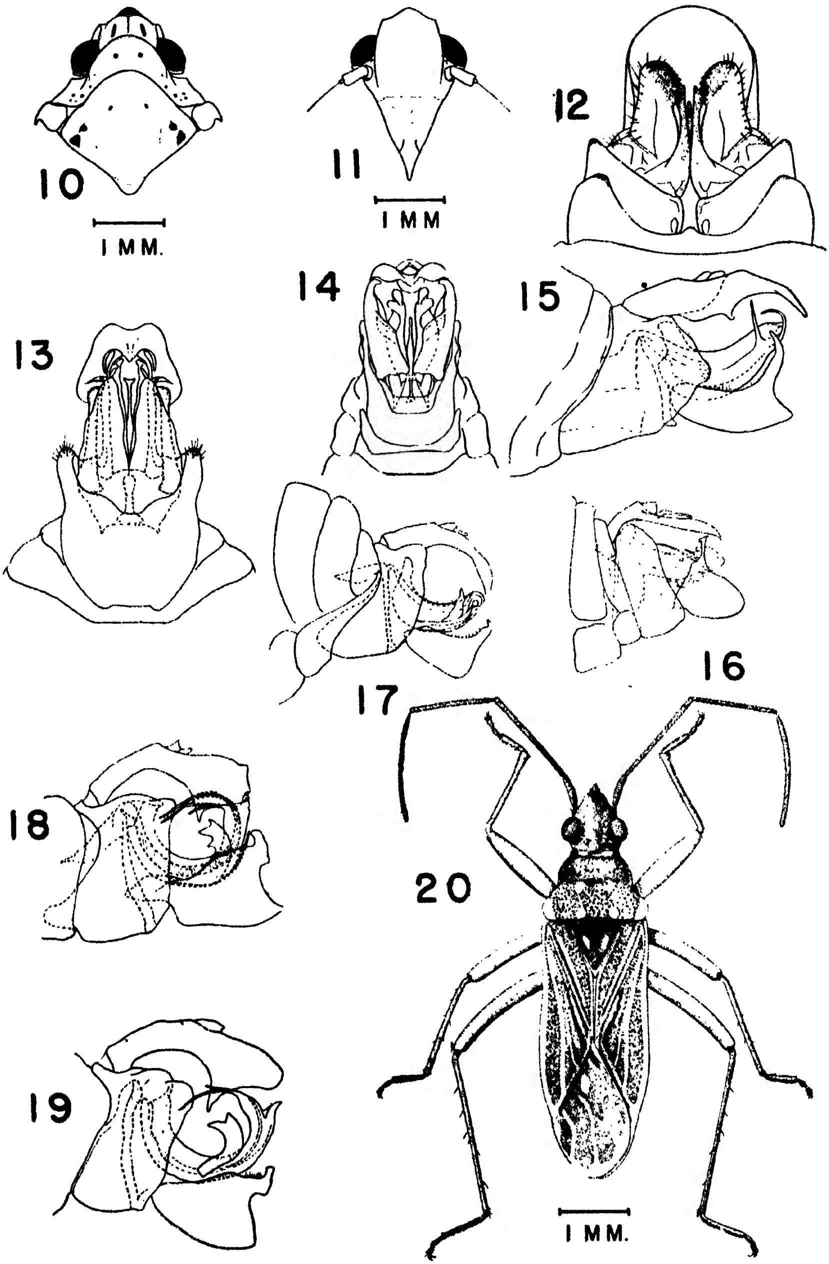


(Ramos: Insects of Mona Island (West Indies))



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THE CONTROL OF RHIZOCTONIA DAMPING-OFF OF PEPPER AND EGGPLANT IN PUERTO RICO

By LUIS A. ALVAREZ GARCÍA

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INTRODUCTION

Serious outbreaks of damping-off of vegetable crops have frequently been reported from almost every locality in the Island. The disease is more likely to occur during periods of heavy rainfall, when conditions of soil moisture and temperature are unsuitable for proper seedling development. Farmers sometimes complain of poor viability of seed when it is apparent that the low percentage of germination is due to pre-emergence failure caused by damping-off organisms. Heavy damping-off losses have occured in seed and plant beds of pepper and eggplant. In many instances, several thousand seedlings of these vegetables have succumbed to the disease. The disease has appeared in naturally contaminated soils as well as in artificially recontaminated, steamed or formaldehyde treated, soils.

Damping-off of vegetable crops in Puerto Rico has been ascribed by various workers to attacks by fungi of the genera *Pythium*, *Phytophthora*, *Phomopsis* and *Rhizoctonia.*

Nolla (10) found *Phomopsis vexans* (Sacc. & Syd.) Harter responsible for damping-off, blight and fruit rot of eggplant. *Pythium debaryanum* Hesse and species of *Phytophthora* were reported causing damping-off of tomato, pepper and eggplant.

Matz (7), in a study of the *Rhizoctonias* of Puerto Rico, reported isolates from beet, carrot, celery, tomato, citrus, eggplant, lettuce, corn, pepper, celeriac, banana, field pea, Natal plum (*Carissa grandiflora*), bean, "yautía" (*Xanthosoma* sp.) and hollyhock. No attempt was made to establish pathogenicity. The Rhizoctonia were studied morphologically and physiologically and cataloged by species, i. e., *R. microsclerotia*, *R. dimorpha*, *R. macrosclerotia*, *R. grisea*, *R. solani*, *R. ferrugena*, *R. pallida*, *R. alba* and *R. melongena.*

Tucker (16) reported strains of *Phytophthora capsici* Leonian, *P. palmivora* Butler and *P. parasitica* Dast. causing damping-off of tomato and eggplant. In Puerto Rico *P. capsici* has been found attacking only peppers.

Other organisms might possibly be associated with damping-off of pepper, tomato and eggplant seedlings in seed and plant beds in Puerto Rico. Aside from Nolla's (11) work on the control of damping-off of tomato, pepper and eggplant caused by *Pythium debaryanum*, *Phytophthora nicotiana* and *Phomopsis vexans*, the latter attacking only eggplant, very little attention has been given to the serious matter of controlling damping-off of vegetables in Puerto Rico.

Fungicides for seed and soil treatments have been tested and recommended in other countries to minimize losses due to damping-off of vegetables and other crops. It is a well-known fact that damping-off organisms

react differently to fungicidal treatments. This depends not only upon their specificity for toxic chemicals, but also upon variations of soil composition and climate. The occurrence of different physiological strains of fungi is also recognized. These factors account for the apparent discrepancies in effectiveness of fungicides for the control of certain plant diseases.

The present paper, therefore, treats of essential information regarding the occurrence of a damping-off of pepper and eggplant in seed and plant beds in Puerto Rico, the causal agent, the symptoms produced on infected seedlings, the life history of the pathogen, the influence of environmental conditions on damping-off, and the effect of seed and soil treatment with fungicidal chemicals for control of the disease.

CAUSAL ORGANISM

During the summer and fall rainy season of the years 1941, 1942 and 1943, the Genetics Department of this Station was confronted with a serious case of damping-off of pepper (*Capsicum annuum* and *C. frutescens*). Several hundred seedlings obtained from crosses of the hot Mexican pepper known as "Cuaresmeño" and the variety "California Wonder", grown in flats in steamed soil (15 pounds for 2 hours), or formaldehyde treated (1 part to 40 of water), were completely lost due to damping-off. The soil used in every instance was a mixture of three parts of alluvial clay loam soil and one part of "cachaza", decomposed filter press cake from the sugar mills. Cultures in agar plates were made by planting pieces of infected tissues of pepper seedlings showing symptoms of damping-off. Tissue plantings were also made from diseased eggplant varieties "Rosita" and "Puerto Rican Beauty" seedlings found in seed and plant beds. Tissue plantings of diseased tomato, pepper and eggplant seedlings from the field were made during the course of the two years.

In a great majority of plates a rapidly growing fungus with coarse, septate, and branching mycelium, was obtained. The mycelium turned slightly brownish or dark-brown with age, grew irregularly, and formed large, aerial, coriaceous masses of sclerotia in culture. The characteristics of the organism in culture and in plants indicate a strain of *Rhizoctonia solani* Kühn.

The general cultural characters of the isolates from pepper and eggplant seedlings conformed very closely with those already described by Matz (7) for *R. solani*. Several *Fusaria* were also obtained on poured plates and were isolated in pure culture. Fifty isolates of *R. solani* were compared morphologically and physiologically, and there were no apparent differences among them. Pure cultures of *R. solani* and other organisms were obtained by spore and hyphal-tip isolations and were labelled R-1,

R-3, R-50, F-1, F-2, F-15; indicating *Rhizoctonia* and *Fusarium*, respectively.

ECONOMIC IMPORTANCE AND DISTRIBUTION

The widespread occurrence of *Rhizoctonia* damping-off and the fact that the pathogen can live indefinitely in the soil, makes this a very serious disease of vegetable crops in Puerto Rico.

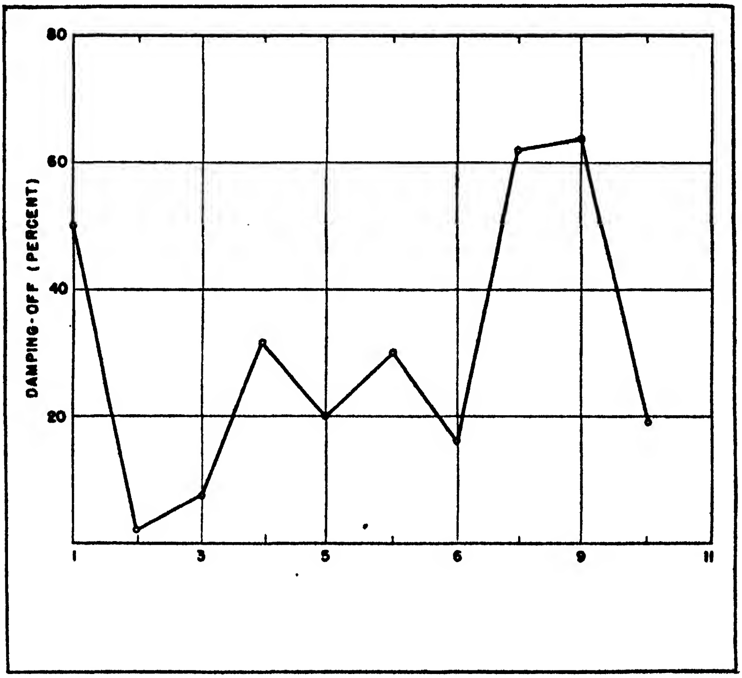

FIG. 1. Distribution of *Rhizoctonia solani* in various fields in Station ground

Damping-off in seed and plant beds has been very serious and 100 per cent losses have frequently been reported.

Preliminary observations of the incidence of the disease in pepper and eggplant seedlings have revealed a high degree of soil infestation of *Rhizoctonia* sp. in various fields at the Station.

The general distribution of these organisms in various fields is shown in graph No. 1. Fig. 1.

PATHOGENICITY

Eight isolates of *Rhizoctonia solani* from different seedbeds were tested for pathogenicity. Four *Fusaria* were similarly selected for comparative tests with the *R. solani* isolates.

Four-inch pots filled with a soil mixture of three parts alluvial, clay loam soil and one part of "cachaza" were steamed for two hours at 15 pounds pressure. Soon after cooling, the pots were arranged in 10 blocks of 13 pots each, on a cement table inside the plant pathology greenhouse. Pots of each block were numbered 1 to 13 at random, thus allowing 10 replicates for each culture.

Each corresponding pot of each block was infested with a corresponding culture. This was accomplished by taking one inch of soil from each of the 10 corresponding pots, mixing the soil in a steam sterilized, enameled pan; and adding to the soil a mixture of small pieces of mycelium and sclerotia from a mycelial mat 10 cm. in diameter. One separate culture of *R. solani* or one of *Fusarium* sp. was used in each soil treatment. The mycelial mat was obtained by growing the organisms separately in Coon's solution. The *Rhizoctonia* and the *Fusaria* grew well in this medium, the former producing abundant sclerotia and the latter abundant conidia. The mycelial mat of each culture was macerated with sterile sand in a sterile mortar thus obtaining a uniform mixture of the soil and macerate. One inch of the infested soil mixture was added to each corresponding pot in each block so that a uniform distribution of inoculum resulted.

Control pots were treated similarly but were not infested; sand only was added. Thirty eggplant seeds of the variety "Rosita" were sown in each replicate pot, totalling 300 seeds per treatment. The seed was sown one half inch deep and watered immediately. The rapid evaporation of water in clay pots necessitates daily watering. Records of germination, pre-emergence and post-emergence failures were taken daily for a period up to 15 days after germination. Damping-off occurred and killed most seedlings within the first three to five days after emergence (table 1).

The results obtained show that all *R. solani* isolates from eggplant and pepper seedlings, causing damping-off in seedbeds at the Station, are virulent and perhaps belong to the same strain. No significant differences existed among them, though there existed a marked difference in pathogenicity between the *R. solani* isolates and those of *Fusaria*. The results also show that the latter organisms are of no apparent importance in producing damping-off in pepper and eggplant. Tomato seedlings showed marked resistance to *Rhizoctonia*.

Reisolations from each corresponding group of 10 replicates of all damped-off seedlings yielded, in every instance, the fungus *R. solani*.

THE DISEASE

Post-emergence symptoms of damping-off of pepper and eggplant were characterized by the appearance of water-soaked areas on succulent stems at the soil level. The affected areas became black, necrotic, shrunken, and

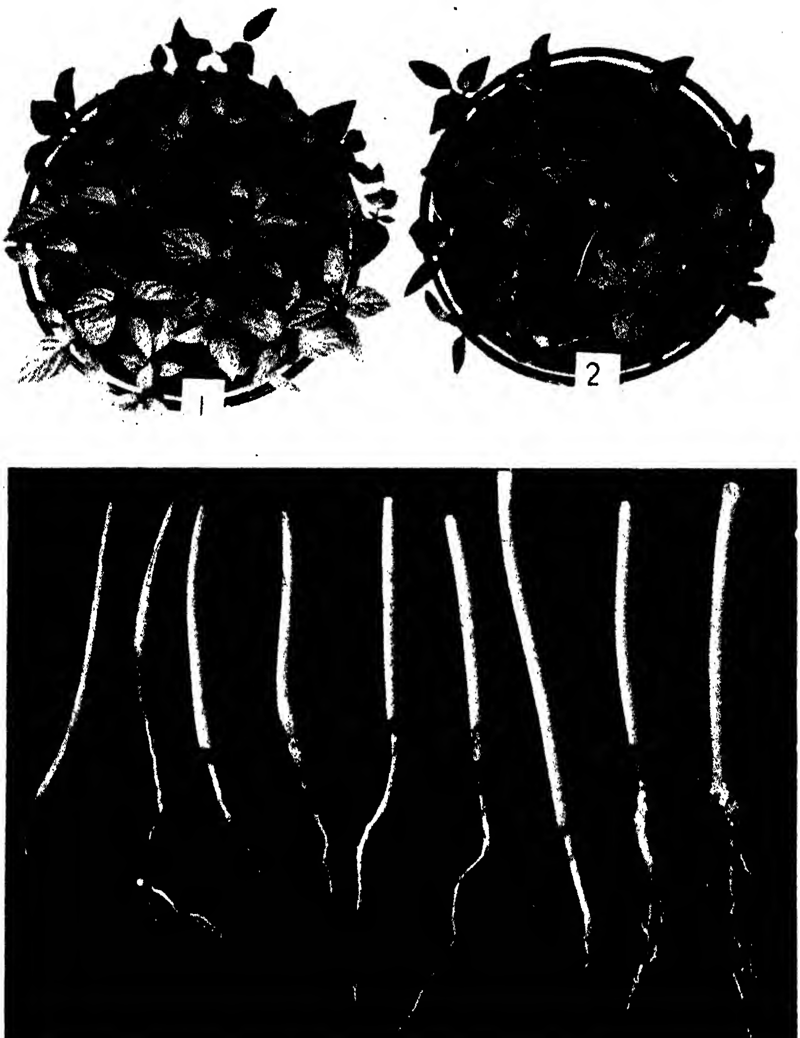

FIG. 2. Pepper seedling grown in the greenhouse on (1) left, soil artificially contaminated with *Rhizoctonia solani* (2) right, on steamed soil (3). Pepper seedlings grown on contaminated soil showing collar rot injury due to infection with *Rhizoctonia solani*.

the plants toppled over and dried up. The symptoms appeared almost immediately after emergence of seedlings, or within the first week of growth, when the tissues were succulent and more susceptible.

TABLE 1

Pathogenicity trial with single-hyphal-tip and monosporial cultures of fungi upon eggplant in steamed soil. Three hundred eggplant seeds variety "Rosita" were sown for each treatment*

Fungus	Culture number	Damping-off –failures				Total failure§	
		Pre emer-gence†	Pre emer-gence‡	Pre emer-gence	Post emer-gence		
		number	*number*	*per cent*	*per cent*	*number*	*per cent*
Rhizoctonia solani	R-1	200	40	85	100	240	100
Strains	R-2	189	40	84	79	229	95
"	R-3	167	39	69	50	196	81
"	R-7	215	25	89	100	240	100
"	R-9	195	39	81	86	234	97
"	R-11	199	22	82	53	221	92
"	R-15	222	17	92	94	239	99
"	R-41	211	20	91	78	231	96
Fusarium spp.	F-1	30	5	12.5	2.4	35	14
	F-7	19	0	8	0	19	8
	F-9	10	7	4.5	3	17	7
	F-13	17	3	7	1.2	20	8.5
Control	¶	5	–	2	0	5	2

* Three hundred seeds 80 per cent germination in control.

† Pre-emergence failure, per cent $= \dfrac{240\text{-seed germinated}}{240}$.

‡ Post-emergence failure, per cent $= \dfrac{\text{Post-emergence failure}}{240\text{-seed germinated}}$.

§ Total failure, per cent $= \dfrac{\text{Pre} + \text{post-emergence failures}}{240}$.

¶ Not inoculated.

Analysis of variance for mean-square difference between organisms, according to data for table 1

	Degrees of freedom	Sum of squares	Mean square	F[1]
Total	129	14,404		
Blocks	9	8,479		
Treatment	12	3,913	326	12**
Error	108	2,012	18.6	

** Significant at the 1 per cent point

Pepper and eggplant were very susceptible during the first week after emergence. There was a marked resistance with increasing age of seedlings. Under field conditions, damping-off of pepper and eggplant was

characterized by the blackening and shrinking of stem tissues at the soil level and extending up the stem, never down to the roots. In very wet soils, or during periods of heavy rainfall, the fungus was observed as a white web on the necrotic stem lesions. No sclerotia, however, were found on infected tissues of diseased plants (fig. 2. photo of diseased pepper seedlings).

TEMPERATURE

Temperature Relations of Rhizoctonia Solani

Cultures of *R. solani* were grown on potato two per cent dextrose agar and incubated at different temperatures. Four duplicates were made for

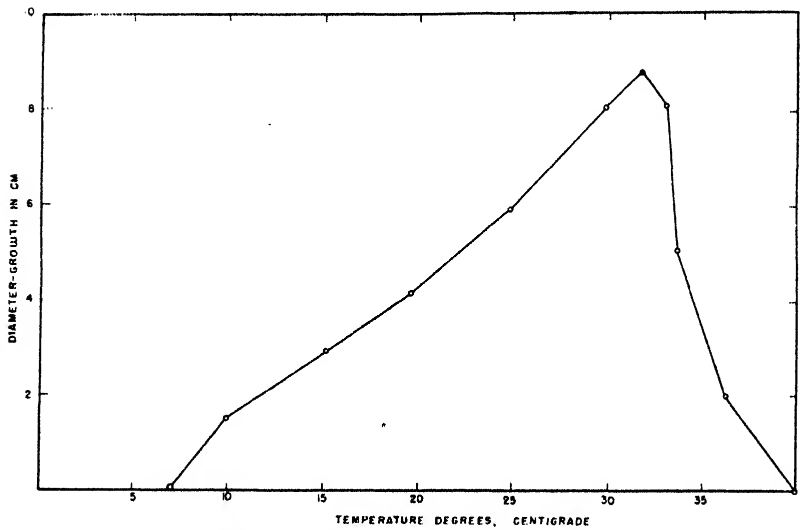

FIG. 3. Growth of *Rhizoctonia solani* in 90 hours at various temperatures

each incubation temperature. Measurements of two diameter at right angles to each other for each colony were taken daily and increments in diameter of growth during a three day period also were taken. The average diameter for each set of four plates was recorded. Maximum growth appeared to be at 28–32°C., and a sudden decrease occurred at 34°C. Very slow growth resulted below 20°C.

High temperatures were found favorable to the occurrence of *Rhizoctonia* damping-off. Pathogenicity tests conducted in greenhouses (22–40°C.) showed significant results as to the amount of damping-off caused by strains of *Rhizoctonia*. The incidence of the disease, therefore, seems to substantiate the published statements that strains of *Rhizoctonia* cause damping-off at high temperatures. In our tests, the average temperature was approximately 28°C.

ACIDITY

Effect of pH of Substrate on Growth

To determine a possible correlation of soil acidity with the development of the organism, *R. solani* was grown on potato two per cent dextrose agar adjusted to varying pH value. Lots of four plates, each lot adjusted to a different pH value, were separately planted with mycelial disks, approximately 0.5 cm. in diameter, of the fungus and set aside at 28°C., in the dark. Twenty-four hour increments in diameter-growth of the colonies were recorded. These measurements showed that the organism grew favorably at pH values near neutrality or slight alkalinity.

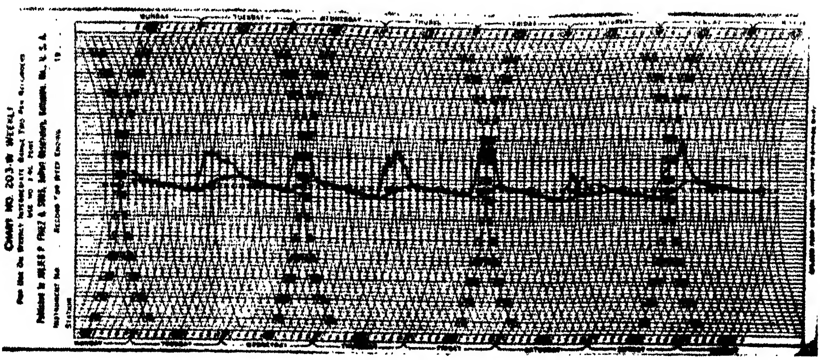

FIG. 4. Graph showing weekly fluctuation of soil and air temperatures in the greenhouse. Smooth curve represents soil temperature and broken curve air temperature.

The growth of *R. solani* species at varying pH values of substrate has been determined by many investigators and there is much divergence among the observations reported (6, 13). The variations reported for the optimum acidity for growth may be explained on the basis of diversified strains of the fungus.

Acidity and Damping-off

No experiments were conducted to determine the effect of soil acidity on the occurrence of damping-off. It was observed that all the pH determinations of soil samples taken from seed and plant beds where the disease had been serious, ranged from pH 5.00–6.50. Observations reported for similar investigations have shown that damping-off caused by *Rhizoctonia* spp. is abundant in either acid or alkaline soils (3, 13).

Soil mixtures of three parts of alluvial, clay loam soil and one part of "cachaza" are generally used in the Station in seed and plant beds. They

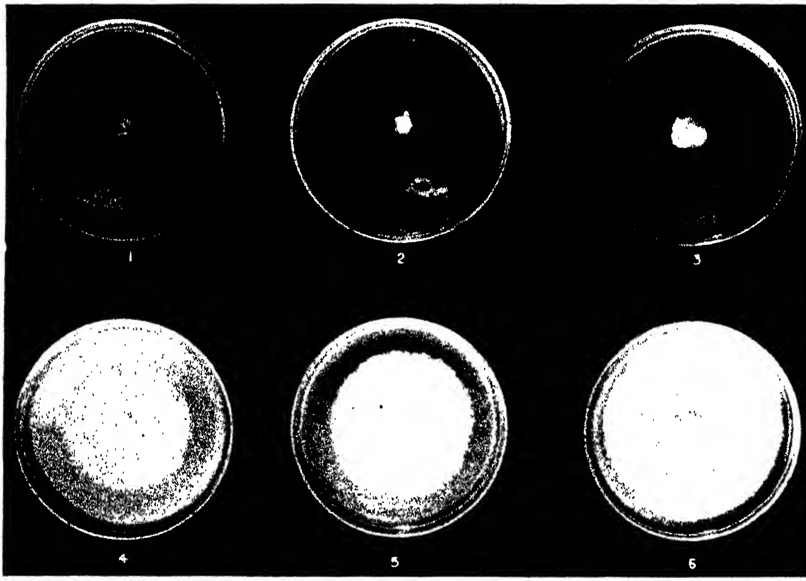

FIG. 5. Growth of *Rhizoctonia solani* in 90 hours at 28°C., on potato dextrose agar adjusted to varying pH's values of 1.0, 1.2, 1.5, 5.49, 601 and 7.08.

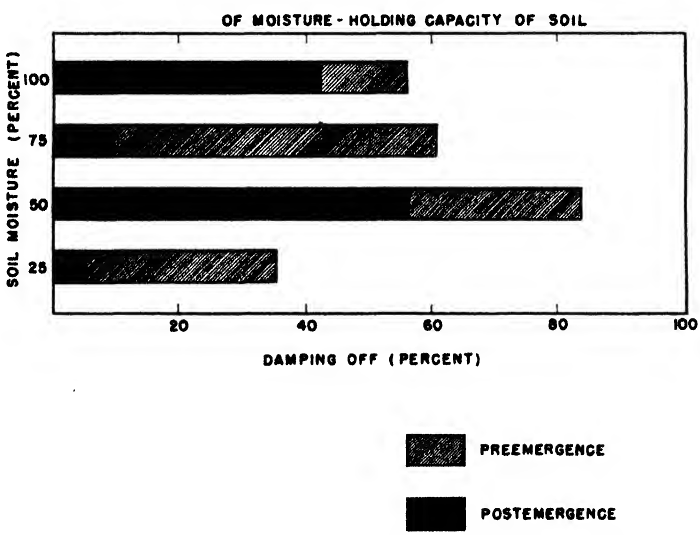

FIG. 6. Damping-off of eggplant seedling caused by *Rhizoctonia solani* at various percentages of the moisture-holding capacity of the soil.

have pH values approximately neutral. In a great majority of cases the reaction has been a pH of 6.54.

MOISTURE

Soil Moisture

It is claimed by many authors (2, 3, 13) that the percentage of soil moisture greatly influences the development of damping-off. High moisture content of the top soil is considered more important than the total percentage of water in the soil.

Rainfall: Agricultural Experiment Station—Rio Pedras, P. R.

From January 1932 to December 1943

Data compiled by the Department of Agronomy

Year	January	February	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Average 12 yrs.
1932	6.03	0.65	1.16	1.65	13.03	8.96	7.12	7.55	11.94	10.63	4.30	4.43	77.45	
1933	3.20	1.69	5.23	2.99	7.00	4.02	5.98	10.18	13.36	6.03	5.21	5.59	70.48	
1934	5.72	1.88	3.34	1.12	2.34	6.05	7.14	4.70	6.29	6.16	6.08	12.85	63.67	
1935	2.80	6.10	1.73	1.66	7.34	5.29	6.98	7.45	6.00	6.62	3.86	1.97	57.80	
1936	1.58	1.03	.88	1.87	16.11	5.49	10.42	8.37	8.92	6.85	2.38	8.61	72.51	
1937	17.39	1.08	.47	1.54	2.08	4.90	9.25	12.53	9.17	5.42	6.32	4.14	74.29	
1938	3.89	3.23	3.45	2.20	5.14	17.55	4.56	6.40	5.75	7.47	10.20	5.39	75.23	
1939	4.01	3.85	3.79	2.78	13.04	3.32	8.48	9.60	8.23	8.85	12.83	3.65	82.43	
1940	4.21	4.24	.99	9.67	12.23	4.84	5.25	4.44	2.92	6.12	7.47	3.64	66.02	
1941	3.13	.73	1.78	5.71	16.45	11.24	9.80	8.90	7.25	5.72	7.61	3.83	82.15	
1942	1.63	2.32	2.18	6.89	5.39	4.42	10.07	7.60	10.32	8.27	9.78	4.13	73.00	
1943	15.55	4.95	4.86	6.74	7.22	8.30	8.66	14.12	4.00	7.81	.85	2.84	85.05	73.34

Data from the United States Department of Agriculture Weather Bureau

Average monthly and annual rainfall

	Elevation	No. of years	January	February	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	feet														
Río Piedras	75	36	4.96	3.28	3.45	4.52	6.90	6.10	7.69	7.90	8.27	6.63	6.99	6.33	73.02

Sets of four one-gallon enameled pots filled with the above-mentioned soil mixture (pH 6.54) were steamed for two hours at 15 pounds pressure, and soon after cooling were placed on cement tables in the plant pathology greenhouse. The weighing method was used to determine the effect of soil moisture on damping-off. No attempt was made to reduce the evaporation of water from the surface layers of the soil. The purpose was to conduct the experiment by duplicating, as nearly as possible, the conditions in seed and plant beds where the surface layers of the soil are free to evaporate

water at all times. The practical aspect of the problem has primarily been considered.

The percentage of damping-off was very high. The surface layers of the soil were saturated in all cases because water was added daily to replace that lost by evaporation.

The results revealed that the amount of soil moisture is very important, provided that the water is near the surface layers. In all probability, different results could have been obtained if water had been supplied from the bottom by capillarity. Farmers apply water by means of sprinklers and use capillary irrigation in only a few instances.

TABLE 2

Varietal behavior of Capsicum annuum and C. frutescens when grown on Rhizoctonia solani artificially infested soil

Number	Variety of pepper	Amount viable seed sown	Damping-off failure				Failure	
			Pre-emergence failure	Post-emergence failure	Total			
					Pre-emergence	Post-emergence		
			number	*number*	*per cent*	*per cent*	*number*	*per cent*
1	Early Giant	800	415	83	52	22	498	62
2	Windsor A	800	400	175	50	43	575	72
3	Tabasco	800	242	177	30	32	419	52
4	King of the North	800	350	59	44	13	409	51
5	Red Chili	800	131	43	16	6	174	22
6	Maule's Red Hot	800	135	136	17	20	271	34
7	Sweet Meat Glory	800	114	57	14	8	171	21
8	Large Early Neapolitan	800	165	57	21	9	222	28
9	Large Red Cheyenne	800	70	140	9	19	210	26
10	Hungarian's Way	800	144	127	18	19	271	34
11	Chinese Giant	800	155	56	19	9	211	26
12	Fordhook	800	496	85	62	28	581	73
13	Large Chemy	800	85	40	11	6	127	16
14	Sweet Banana	800	301	55	38	11	356	45
15	World Beaters	800	63	82	8	11	145	16
16	Yellow Oskosh	800	66	43	8	6	109	14
17	Ruby King	800	341	81	43	18	422	53
18	Bull Nose	800	152	96	19	15	248	31
19	California Wonder	800	247	97	31	18	344	43
20	Large Bell Hot	800	242	54	30	10	296	37
21	Sunny Broock	800	338	44	42	10	382	48

$$\text{Per cent pre-emergence} = \frac{\text{seed sown} - \text{seed germinated}}{800}.$$

$$\text{Per cent post-emergence} = \frac{\text{post-emergence failure}}{\text{seed sown} - \text{pre-emergence failure}}.$$

Summary of analyses of variance for data of table 2

Comparison of failures	DF	Sum of squares	Variance	F.
Post-emergence (per cent basis) failure				
Total	167	76,000		
Blocks	7	4,447		
Varieties	20	7,337	366.8	0.80
Error	140	64,216	458.7	
Pre-emergence failure				
Total	167	121,875.9		
Blocks	7	20,249.8		
Varieties	20	41,549.6	2,077.5	4.84*
Error	140	60,076.4	429.1	
Total failure				
Total	167	132,826		
Blocks	7	12,286		
Varieties	20	36,358	1,817.9	3.02*
Error	140	84,182	601.3	

* Significant at the 1 per cent level.

Reports of the Weather Bureau for the last 36 years show that eight months in a year have a monthly average rainfall of more than 6 inches. The heavy nature of the soil around Río Piedras and the abundant rainfall favor the development of damping-off.

VARIETY TEST

Testing Pepper Varieties for Resistance to Damping-off

Twenty-one varieties of sweet and hot peppers *Capsicum annuum* and *C. frutescens* were tested for resistance to damping-off caused by *Rhizoctonia solani*. One hundred seeds of each variety were sown in rows in blocks in a pan and replicated eight times, a total of 800 viable seeds per variety, considering in each case the percentage of germination in sterilized soil. The soil used was the above-mentioned mixture with "cachaza," to which macerates of sclerotia and mycelium of pure cultures of the organism were added. The seed was sown ½ inch deep and the soil was watered immediately after sowing with a sprinkler, until saturation resulted. The pan was drained at the bottom to prevent water logging.

Diseased seedlings from each row were pulled up for tissue plating. *R. solani* constantly was associated with damping-off.

There were significant differences in susceptibility in the pre-emergence stage of development of the pepper varieties investigated. It is apparent,

therefore, that at this early stage of development some varieties are either more susceptible to attack by *R. solani* than others, or the possibility exists that even though an equal amount of seeds was sown, based on germination tests, they did not germinate according to expectancy.

Records obtained during the post-emergence stage demonstrated no differences in susceptibility of varieties tested. Analysis of pre- and post-emergence failures showed that some varieties were more susceptible than others. All varieties were equally susceptible to damping-off, if only the post-emergence failure was considered.

Analysis of variance of a varietal test with eggplant varieties "Rosita," "Puerto Rican Beauty" and "Black Beauty" showed no significant differences in susceptibility. Tomatoes were also attacked by the isolates of *R. solani*. Pritchard and Porte (12) found in a study of collar rot of tomatoes that a strain of *R. solani* caused only three per cent infection in seedbeds, while *Verticillium lycopersicii* and *Macrosporium solani* produced 64 and 75 per cent infection, respectively.

FUNGICIDAL TREATMENT

Effect of Seed and Soil Treatment in Controlling Damping-off

The value of seed and soil treatment for the control of damping-off of many vegetable crops has been well established. Seed and soil treatment is most effective in soils with a moderate "inoculum potential". The effectiveness of various fungicidal dusts recommended for seed and soil disinfection was tested for the control of damping-off of pepper and eggplant caused by *Rhizoctonia solani*. Both naturally and artificially inoculated soils consisting of three parts of alluvial, clay loam soil and one part "cachaza," pH 6.54, were used in the tests.

Two hundred four-inch pots were filled to one inch from the top with the above-mentioned soil mixture. The pots were steamed for two hours at 15 pounds pressure and soon after cooling were placed on sand beds in an insect-free insectary inside a greenhouse. The plan for the test was a random-block design consisting of 10 blocks of 40 pots each. Twenty of the 40 pots of every block were filled with naturally infested soil. Pots not steamed were labelled with odd numbers from 1 to 39. Steamed pots were labelled from 2 to 40. Pots 2 to 40 were infested with equal proportions of macerates of mycelial mats of *Rhizoctonia solani* grown in Coon's liquid medium.

Seed Treatmeni

Five hundred seeds in each case were treated separately with one chemical, except groups 19 and 20 which served as checks. Sufficient chemical

dust was added to every lot of seed to cover its surface. The surplus chemical was separated by means of a fine-mesh-wire screen.

Twenty-five seeds of each treatment were sown in corresponding pots in each block. The pots were watered with sterile water immediately after sowing the seed.

Analysis of the results indicated a very definite effect upon the type of infestation and the effectiveness of the fungicides. Significant differences were obtained among the fungicides tested when compared with either naturally or artificially infested soil. The mean square of variance corresponding to differences between fungicidal treatments and the type of infestation, the interaction of type and infestation, and their mean square for error, exceeded the one per cent level, indicating, therefore, the degree of effectiveness of the treatments.

Interpretation of Results Obtained from Analysis of Variance

Pre-emergence Failure:

On naturally infested soil: The least significant difference among treatments showed that the degree of damping-off during the pre-emergence stage of seedlings development was low, indicating a low "inoculum potential" of the soil. None of the fungicidal treatments tested seemed to promote a better germination of the seed because of either fungicidal or perhaps stimulatory effects. Statistically, these fungicides were equally ineffective when compared with the check, number 19. This can be interpreted on the basis of low "inoculum potential" of the soil which enabled the seed of all pots to germinate equally well.

However, "Spergon," "Arasan," "1155 H. H.," "2% Ceresan" and "New Improved Ceresan" apparently were injurious to the seed. This is indicated by the low percentage of germination which statistically is significant when compared with the check, number 19.

On artificially infested soil: "Semesan," "Z-O," "Dipdust," "Cuprous Oxide," "Zinc Oxide" and "Coppercarb" were equally effective in controlling pre-emergence failure. The percentage of germination was statistically higher when compared with the corresponding number of seedlings emerging in the check, number 20.

"New Improved Ceresan," "1155 H. H.," and "2% Ceresan" again proved toxic to the seed, and reduced viability materially and statistically when compared with the check, number 20.

Post-emergence Failure:

On naturally infested soil: "Coppercarb," "Barbak D.," "Fermate" and "Dipdust" showed some harmful effects because the percentage of

failure was statistically higher than that obtained in the check, number 19 which was zero. Other treatments were equally ineffective in preventing post-emergence damping-off.

On artificially infested soil: "Spergon," "Cuprous Oxide," "1155 H. H.," "2% Ceresan," "Cupric Oxide" and "Barbak D." were equally effective in preventing post-emergence failure. The percentage of surviving seedlings was statistically higher than that obtained in the check, number 20. "New Improved Ceresan," "Semesan Jr." and "Dipdust" treatments were statistically inferior when compared with the check, number 20.

Pre- and Post-Emergence Failure:

On naturally infested soil: No fungicide caused statistically higher percentages of germination and development of emerged seedling than that observed in the check, number 19. "Spergon," "1155 H. H.," "2% Ceresan" and "New Improved Ceresan," however, reduced the germination and development of seedlings below that of the check, number 19.

On artificially infested soil: "Bayer Compound No. 1494" was effective in preventing post-emergence damping-off of seedlings, either before or after emergence of the seedlings. The effect was statistically higher than that obtained in the check, number 20. "New Improved Ceresan" demonstrated once more a toxic effect on the seed, as shown statistically in comparison with the check, number 20.

Soil Treatment

The same procedure used in preparing pots for testing the effectiveness of the seed treatment was followed, except that the soil and not the seed was treated with chemical dusts. All treatments were applied at the rate of 1.0 gram per square foot of soil, except that for zinc oxide, which was applied at the rate of 10.00 grams per square foot of soil. The soil for each treatment was separately and evenly mixed with one chemical. After a thorough mixing, the infested soil was placed in 10 corresponding pots and one pot was distributed in each block.

Result of Analysis of Variance for Soil Treatment:

Pre-emergence Failure: On naturally infested soil: In accordance with results obtained from soil treatment, all fungicides were apparently equally ineffective in preventing damping-off, when compared statistically with the check, number 19. None of the treatments were either better or worse than the check. No treatment showed toxic effects upon the viability of the seed.

On artificially infested soil: All treatments were equally ineffective in preventing pre-emergence failure and none were better or worse than the

TABLE 3

Effect of seed treatment on pre-emergence, post emergence and total emergence failure of eggplant seedlings, variety "Rosita." Seed sown, 250. Soil infested with Rhizoctonia solani (isolated from eggplant seedlings)

Number	Trade name	Treatment	Manufacturing house	Damping-off: Pre-emergence	Damping-off: Post-emergence	Damping-off: Total: Pre-emergence	Damping-off: Total: Post-emergence	Total failure	Total failure
				number	*number*	*per cent*	*per cent*	*number*	*per cent*
1	Arasan	Tetramethyl-	Bayer Semesan Co.	25	0	10	0	25	10
2	"	thiurum-bisul- fide. 50%.	"	81	138	32	82	219	88
3	Spergon	Tetrachloro-para-	U. S. Rubber Co.	67	18	27	10	85	34
4	"	benzoquinone	"	95	91	38	59	186	74
5	New improved ceresan	Ethyl mercury-phosphate 5%	Bayer Semesan Co.	247	0	99	0	247	99
6	" "		"	249	0	100	0	249	100
7	Fermate	Ferric-dimethyl	Graselli Chem. Div.	32	20	13	9	52	21
8	"	di thio-carbamate	" "	82	108	32	64	188	75
9	Du Bary 1155 H. H.	Ethyl mercury-iodide 5%.	Bayer-Semesan Co.	151	1	60	1	152	61
10	" "		"	173	31	69	40	204	82
11	Dipdust	Hydroxy mercury-	Bayer-Semesan Co.	25	23	9	10	46	18
12	"	chloro-phenol sulphate 6%	"	45	171	18	83	216	86
13	Semesan	Hydroxy mercury-	Bayer Semesan Co.	23	0	9	0	23	9
14	"	chlorophenol. 30%	"	21	161	8	70	182	73
15	2% Ceresan	Ethyl mercury-	Bayer-Semesan Co.	219	0	88	0	219	88
16	"	chloride. 2%	"	224	9	90	35	233	93
17	Z-O			22	0	8	0	22	9
18	"			30	141	12	64	171	68
19	Check			27	0	11	0	27	11
20	"			138	70	55	25	208	83
21	Coppercarb	Copper carbonate	Tennessee Copper	35	33	14	15	68	27
22	"	" "	Corp.	74	131	30	74	205	82
23	Cuprocide	Cuprous oxide	Rahn & Hass Co.	34	20	14	9	54	22
24	"	" "	"	93	80	37	51	173	69
25	ZN-O		Rahn & Hass Co.	27	0	11	0	27	11
26	"		"	73	106	29	60	179	72
27	Cupric oxide	Cupric oxide	General Chemical	33	7	13	3	40	16
28	" "	" "	Co.	123	38	49	30	161	64
29	Uspulun	Chlorophenol mercury	Bayer-Semesan Co.	61	2	24	1	63	25
30	"	" "	"	144	85	58	80	229	92
31	Barbak D	Mercuric phenyl cyanamid 6%	Am. Cyanamid & Chem. Co.	98	1	39	0	99	40
32	"	"	"	161	35	64	39	196	78
33	Dupont no. 1		E. I. Dupont Co.	15	8	6	3	23	9
34	"		"	164	46	66	53	210	84
35	Cuprous oxide	Cuprous oxide	Mallinckrodt Co.	25	1	10	0	26	10
36	" "	" "	"	165	85	66	100	250	100
37	Semesan Jr.	Ethyl mercury phos-	Bayer-Semesan Co.	40	22	16	10	62	25
38	"	phate 1%	"	80	149	32	88	229	92
39	Bayer compound no. 1494		Bayer-Semesan Co.	66	20	26	11	86	34
40	" "		"	147	74	59	72	221	88

(1) Odd numbers = naturally infested soil.
(2) Even numbers = artificially infested soil.
(3) Per cent calculation on the basis of 250 seeds that germinated in controls.

Analysis of variance for table 3

Failures	Degrees of freedom	Sum of squares	Variance	F.
Pre-emergence				
Total	399	26,094.1		
Blocks	9	572.28		
Treatments	39	18,060.2	463.08	21.78*
Kind of infestation	1	2,475.0	2,475.0	116.46*
Types	19	6,923.0	364.0	17.12*
Infestation x types	19	8,662.2	456.0	21.45*
Error	351	7,461.62	21.25	
Post emergence (per cent basis)				
Total	399	530,526		
Blocks	9	6,880		
Treatments	39	446,162	1,145.0	52.0*
Kind of infestation	1	327,177	327,177	1,032.0*
Types	19	28,342	1,491.2	6.7*
Infestation x types	19	1,563.27	8,227	37.3*
Error	351	77,484	220.0	
Total failure				
Total	399	35,301.5		
Blocks	9	609.5		
Treatments	39	22,511.3	577.2	16.6*
Kind of infestation	1	13,294.1	13,294.1	38.3*
Types	19	5,498.4	289.3	8.3*
Infestation x types	19	3,718.8	195.2	5.6*
Error	351	12,180.7	34.7	

* Significant at the one per-cent level.

check, number 20; but "Spergon," "Dipdust," "Fermate," "New Improved Ceresan" and "Semesan Jr.," apparently reduced germination.

Result of Analysis of Variance for Total Failure: On naturally infested soil: "Spergon," "1105 H. H.," "Zinc Oxide," "Bayer Compound No. 1494," "Semesan," "Dipdust," "2% Ceresan," "Z-O," "Uspulun," "Fermate," "Dupont No. 1." "Cupric Oxide," "Coppercarb," "Arasan," "New Improved Ceresan," "Cuprous Oxide," "Barbak D.," "Cuprocide" and "Semesan Jr." were equally effective in controlling damping-off. None of the treatments was inferior to the check number 19.

On artificially infested soil: "Zinc Oxide" applied at the rate of 10 grams per square foot of soil was effective in preventing damping-off when compared statistically with the check, number 20. "Dipdust," "Cuprous Oxide," "Cuprocide," "Dupont No. 1," "Semesan," "Spergon," "2% Ceresan" and "1155-H. H." were equally ineffective and showed no significant difference to the check.

"Fermate," "Z-O," "Arasan," "New Improved Ceresan," "Coppercarb," "Cupric Oxide," "Uspulun," "Barbak D.," "Semesan Jr." and "Bayer Compound No. 1494" were statistically considered, equally inferior to the check.

TABLE 4

Effect of soil treatments on pre-emergence and post-emergence failure of eggplant seedlings, variety "Rosita." Seed sown, 250. Fungicides applied one week before sowing seed at the rate of 1.0 gram per square foot of soil. Soil naturally and artificially infested with Rhizoctonia solani (isolated from eggplant seedlings)

Number	Trade name	Treatment	Manufacturing house	Damping-off failures				Total failure	
				Pre-emergence	Post-emergence	Total			
						Pre-emergence	Post-emergence		
				number	*number*	*per cent*	*per cent*	*number*	*per cent*
1	Arasan	Tetramethyl-	Bayer-Semesan Co.	60	0	24	0	60	24
2	"	thiurum-bisulfide. 50%	"	246	4	98	100	250	100
3	Spergon	Tetrachloro-para-	U. S. Rubber Co.	44	17	18	8	61	24
4	"	benzoquinone	"	173	50	69	75	223	89
5	New improved ceresan	Ethyl-mercury-phosphate. 5%	Bayer-Semesan Co.	43	21	17	10	64	26
6	" "		"	200	45	80	90	245	98
7	Fermate	Ferric-dimethyl-	Graselli Chem. Div.	57	0	23	0	57	23
8	"	dithio-carbamate	of E. I. DuPont Co.	189	55	76	90	244	98
9	Du Bary 1155-H. H.	Ethyl-mercury iodide 5%	Bayer-Semesan Co.	27	0	11	0	27	11
10	" "		"	215	33	86	94	248	99
11	Dipdust "	Hydroxy-mercury-chlorophenol-sulphate 6%	Bayer-Semesan Co. "	56	3	22	2	59	24
12	Dipdust "	Hydroxy-mercury-nitrophenol sulphate 2%	"	178	47	71	65	225	90
13	Semesan	Hydroxy-mercury-	Bayer-Semesan Co.	49	4	20	2	53	21
14	"	chlorophenol. 30%	"	74	162	30	92	236	94
15	Ceresan	Ethyl-mercury-	"	56	0	22	0	56	22
16	"	chloride. 2%	"	128	95	51	78	223	89
17	Z-O		"	46	10	18	5	56	94
18	"		"	151	98	60	99	249	100
19	Check	Check		66	163	26	89	229	92
20	"	"		93	108	37	69	201	80
21	Coppercarb	Copper carbonate	Tennessee Copper	43	39	17	19	82	33
22	Corona	"	Corp.	117	133	47	100	250	100
23	Cuprocide	Cuprous oxide	Rahn & Hass Co.	32	72	13	33	104	42
24	Yellow Copper oxide	"		73	150	29	85	223	89
25	Aaz	Zinc oxide	Rahn & Hass Co.	31	0	12	0	31	12
26	Speal	"		68	129	27	71	197	79
27	Cupric oxide	Cupric oxide	General Chemical	33	43	13	20	76	30
28	"	"	Co.	72	178	29	100	250	100
29	Uspulun	Chlorophenol mer-	Bayer-Semesan Co.	36	21	14	10	57	23
30	"	cury	"	125	125	50	100	250	100
31	Barbak D	Mercuric phenyl	Am. Cyanamid &	60	41	24	22	101	40
32	"	cyanamid 6%	Chem. Co.	132	118	53	100	250	100
33	Dupont No. 1		E. I. Dupont Co.	59	20	24	10	79	32
34	"		"	93	157	37	100	250	100
35	Yellow Copper oxide	Cuprous oxide	Mallinckrodt Co.	49	18	20	9	67	27
36	"	"	"	109	118	44	84	227	91
37	Semesan Jr.	Ethyl mercury phos-	Bayer-Semesan Co.	72	37	29	21	109	44
38	"	phate 1%		207	43	83	100	250	100
39	Bayer 1494		Bayer-Semesan Co.	46	0	18	0	46	18
40	"		"	130	119	52	99	249	100

(1) Odd numbers = naturally infested soil.
(2) Even numbers = artificially infested soil.
(3) Per cent calculation on the basis of 250 seeds that germinated in controls.

Analysis of variance for table 4

Failures	Degrees of freedom	Sum of squares	Mean squares	F.	Least square difference
					per cent
Pre emergence					64.75
Total	399	34,566.76			
Blocks	9	5,308.96	589.74		
Treatments	39	22,773.76	583.94	31.61*	
Kind of infestation	1	526.2	526.2	28.48*	
Type	19	13,904.2	731.5	39.06	
Type x infestation	19	8,343.36	439.12	23.12	
Error	351	6,484	18.47		
Total Failures					18.65
Total	399	32,390.2			
Blocks	9	156.3			
Treatments	39	29,232.9	749.0	131*	
Kind of infestation	1	27,208.5	27,208.5	477.3*	
Type	19	1,587.85	83.5	14.4*	
Type of infestation	19	536.55	28.2	4.9*	
Error	351	2,001.9	5.7		

* Significant at the one per-cent level.

TABLE 5

Greenhouse toxicity test with eggplant seed "Rosita" dusted with fungicidal chemicals before sowing on steam-sterilized soil. Air temperature inside greenhouse 70–100° F. Relative humidity 40–60%. Soil saturated twice daily

No.	Chemical trade name	Total emergence from 250 seeds	
		number	*per cent**
1	New Improved Ceresan	101	43
2	Du Bary 1155-HH.	139	60
3	2% Ceresan	125	54
4	Check	232	100
5	Spergon	234	100
6	Arasan	209	90
7	Dipdust	232	100
8	Bayer 1494	196	84

* Calculated on the basis of 232 seeds germinated in control.

Analysis of variance for table 5

Emergence	D.F.	Sum of squares	Variance	F.
Total	79	2933		
Blocks	9	84	9.3	
Treatment	7	2037	291	25.9†
Error	63	712	11.3	

† Significant at the 1% level.

It is evident from the results analyzed that the soil treatment was effective in those soils with a low "inoculum potential".

Some fungicides are powerful poisons and under certain conditions might cause death of vegetable seeds. In these studies, 2% "Ceresan," "Du Bary 1155-H. H." and New Improved Ceresan showed this toxicity to eggplant seeds. The results of a toxicity test are shown in table 5.

The least square difference among dust treatments show that "New Improved Ceresan," "Du Bary 1155-H. H." and "2% Ceresan," were equally and significantly injurious to eggplant seed.

CONCLUSIONS AND SUMMARY

Damping-off of vegetable crops in Puerto Rico is of great economic importance. Studies of the causative agent or agents, the symptomatology of the disease, the host-parasite relationship, the distribution, epiphytology and saprogenesis were considered necessary before attempting to formulate pertinent measures of control for this particular problem.

It is apparent from the data obtained that *Rhizoctonia solani* and possibly other organisms are chiefly responsible for the damping-off losses of pepper and eggplant seedlings both in seed and plant beds and in the field.

Damping-off was serious during the first three to seven days after seedling emergence. Thereafter, the ability of the organism to cause damping-off diminished rapidly as the age and hardness of the tissues increased. The injury to recently emerged seedling was a soft, wet and dark rot of stems near the soil level, which soon spread upward and seldom downward. The infected seedlings toppled and finally died. In older plants, the infected stem tissues turned dark and became shrunken. Old plants withstood the disease much better than seedlings. Many plants in the field succumbed to the disease during periods of heavy rainfall.

The *Rhizoctonia* species responsible for the damping-off were very active under our climatic conditions, i.e., a high temperature ranging from 26 to 30°C. the year round, and a high soil and air moisture content. The high water-holding capacity of soils around Río Piedras, and the high rainfall of this locality are important factors for the development of the disease.

The organism grew well at varying pH values of the substrate, particularly at pH values approximately neutral. Considering that pH determinations of top layers of soil from various fields and soil mixtures (three parts of alluvial, clay loam soil and one part of "cachaza") were found to be more alkaline than a pH of 6.00, the presence of the parasite and the development of the disease would be expected in these soils.

The *Rhizoctonia* under consideration has not been observed to produce sclerotia in tissues of diseased pepper or eggplant. However, sclerotia are

produced profusely in culture media, particularly in Coon's synthetic liquid medium. Though it has not been possible to find sclerotia on infected plants, the occurrence of the organism in the soil is apparent from observations made repeatedly upon soil samples. Samples of soil mixtures taken from time to time have shown constantly the presence of the parasite.

Soil sterilization with steam for three hours at 15 pounds pressure was found very effective in preventing damping-off. Formaldehyde was especially effective at a concentration of one part to 20 of water. If precautions were not taken, damping-off was likely to appear in steamed and formaldehyde treated soils due to re-contamination. Many failures occurring in our seed and plant beds were attributed to re-contamination.

In view of the importance of rendering soil mixtures for pots, flats and plant beds free from damping-off organisms, and also in view of the impossibility for many farmers to practice steaming or treating the soil with formaldehyde because of its relatively high cost, several fungicidal dusts were tested for effectiveness in controlling damping-off.

Among the fungicides tested, "Semesan," "Z-O," "Dipdust," "Cuprous Oxide," "Coppercarb," "Zinc Oxide," "Semesan Jr.," "Arasan," "Fermate" and "Spergon" were found equally effective as seed disinfectants for the control of the pre-emergence phase of *Rhizoctonia* damping-off. The small dose used for seed treatment had no residual effect to control post-emergence damping-off. Considering that great losses result every year due to pre-emergence failure, diminishing pre-emergence damping-off is a great saving of time and money.

All treatments for soil disinfection proved equally ineffective in preventing post-emergence failure.

Analysis of total failure, however, showed the effectiveness of soil treatment with "Spergon," "1155 H. H.," "Zinc Oxide," "Bayer Compound 1494", "Semesan," "Dipdust," "2% Ceresan," "Z-O," "Uspulun," "Fermate," "Dupont No. 1," "Cupric Oxide," "Coppercarb," "Arasan," "New Improved Ceresan," "Cuprous Oxide," "Barbak D.," "Cuprocide' and "Semesan Jr." in preventing damping-off in naturally infested soil.

It is apparent that mercurial and copper fungicides have a decided fungicidal effectiveness as seed and soil treatments for controlling *Rhizoctonia solani*. Montieth and Harmon (8) obtained similar results in the case of brown patch of turf caused by *Rhizoctonia* spp. "Uspulun," "Semesan," "Germesan," "Corona 620" and "Corona 640" were found effective. These workers found that mercurials in the form of sulphate, oxide, chloride and nitrate were effective for controlling the disease. Mercurous chloride was the most effective and the most economical considering that

$\frac{1}{5}$ of a pound was as good as one pound of "Uspulun" or "Semesan". Thomas (15) found copper carbonate, mercuric bichloride and "Uspulun" effective at the rate of 1.0–3.0 grams; 0.5–1.00 grams; and 1.0–2.0 grams per square foot of soil, respectively, for controlling damping-off of tomato caused by *Phytophthora* spp. Nolla (11) found: 1) That soil drenching with a one to 50 formaldehyde solution, or applications of 4–4–50 Bordeaux mixture, were effective for controlling damping-off of eggplant caused by *Phomopsis vexans*, though formaldehyde was the most effective and economical. 2) Treatment of soil with corona copper carbonate, at the rate of four grams per square foot of soil, was effective for control of damping-off of tomato, pepper and eggplant caused by *Pythium debaryanum.* 3) Application of copper stereate, at the rate of eight grams per square foot, was found ineffective for control of *Phytophthora parasitica*, but apparently controlled *Pythium debaryanum.* 4) Bayer dust and "Uspulun" were ineffective for controlling damping-off caused by *P. parasitica* and *P. debaryanum.* 5) Two applications of Bordeaux (4–4–50 and 5–5–50 strength at the rate of one half gallon per square foot of soil) were effective in controlling *P. parasitica* and *P. debaryanum*, but were ineffective after damping-off has appeared in seedbeds. 6) Uspulun and Bayer dust were found injurious to tobacco seedlings and ineffective for controlling damping-off. 7) Copper sulphate solution (4–5 pounds in 50 gallons of water) was ineffective at the rate of one half gallon per square foot of soil. 8) Effectiveness of copper fluorosilicate was questionable. 9) Acetic acid (1.0 and $\frac{1}{2}$ per cent solutions) applied at the rate of one half gallon per square foot of soil, did not prove effective for controlling *P. parasitica* and *P. debaryanum.*

These investigations showed that damping-off is a complex problem and many organisms are involved. A combination of control methods appeared, therefore, necessary to assure the destruction of the various pathogens. Steam and formaldehyde are the best methods of soil sterilization. However, our experience has shown that great care has to be exerted if re-contamination of the soil is to be avoided. Bordeaux mixture 4–4–50, applied during the first week after the seedlings emerge, should accompany soil sterilization in order to minimize the chance of damping-off due to reinfestation of the soil.

The Bordeaux was applied at the rate of one half gallon per square foot of soil.

Soil sterilization with steam or formaldehyde are practices that many of our farmers are in no position to use at the present time. It would be very convenient, therefore, to control damping-off by the use of seed and soil treatments with fungicidal dusts already on the market.

Damping-off of tomato, pepper and eggplant in Puerto Rico is, so far as our knowledge is concerned, caused by species or strains of *Phomopsis, Phytophthora*, *Pythium* and *Rhizoctonia.*

Some mercurial and copper compounds have demonstrated their effectiveness for controlling these damping-off organisms in Puerto Rico. The possibility of using one or perhaps a combination of fungicides for controlling these types of damping-off appears to be a very satisfactory control measure.

RESUMEN EN ESPAÑOL

La podredumbre de semillas y plantitas de tomates, pimientos y berenjenas en los semilleros, ya en cajones o ya en el campo, presenta con harta frecuencia un carácter alarmante en nuestro ambiente. Esta podredumbre, conocida comúnmente por "salcocho," representa uno de los problemas más serios que confronta el hortelano.

En Puerto Rico se ha encontrado que varios organismos de los géneros *Pythium*, *Phytophthora*, y *Phomopsis* son responsables de enfermedades de esta clase. Recientemente apareció en semilleros de berenjenas y pimientos en la Estación Experimental una endofitotia de salcocho. Se pudo comprobar que dicho salcocho era causado por el ataque de un hongo cuyas características morfológicas y fisiológicas lo catalogan como una raza de *Rhizoctonia solani* Kühn.

La siembra de semillas de pimientos y berenjenas en tiestos con muestras de tierra representativas de varios campos de la Estación Experimental revelaron claramente la diseminación del hongo mencionado y la gran infestación de dichos terrenos. Este parásito es extremadamente agresivo, atacando las plantitas mucho antes de emerger del terreno y también después de haber emergido.

Los síntomas del salcocho aparecen durante la primera semana de surgir las plantitas, cuando los tejidos del tallo son más susceptibles al ataque del organismo. La enfermedad disminuye gradualmente según van envejeciendo y endureciéndose los tejidos del tallo. Los síntomas se caracterizan por la aparición de manchas acuosas en los tejidos del tallo, a flor de tierra. Luego ennegrecen estos tejidos infectados, síguele un constreñimiento de la parte afectada, y la planta termina por acostarse sobre el terreno del semillero y secarse.

Puede colegirse por lo expuesto anteriormente, que las pérdidas causadas por la podredumbre o salcocho en el estado pre-emergente, como también después de emerger la semilla, son considerables en muchos casos.

La enfermedad aparece más frecuentemente en terrenos húmedos debido a su naturaleza impermeable o por estar mal desaguados, o bien por factores climáticos, principalmente abundante precipitación pluvial. El pH del

terreno, según muchos investigadores, es factor de importancia para el curso de la enfermedad, particularmente en aquellos terrenos en que su pH fluctúa entre 6.00 y 7.00 o es ligeramente alcalino. Dentro de nuestro ambiente, en que prevalece una temperatura bastante alta durante todo el año y que fluctúa entre los 28°C y 30°C., y en que la precipitación pluvial es abundante—en Río Piedras en este caso en que nos ocupamos es de aproximadamente 6 pulgadas por mes—la patografía de la enfermedad se manifiesta con rapidez. Varias pruebas fisiológicas realizadas con este hongo demostraron su gran capacidad para crecer rápidamente en substratos húmedos, de pH variable, entre los 4.44 y 7.15, y a temperaturas entre los 7°C. y 34°C. En general, el hongo crece más rápidamente en un pH alrededor de 7, y a temperaturas entre 28 y 30°C. Este organismo puede crecer en infinidad de medios azucarados. En la disolución de Coon el patógeno produjo abundante micelio y esclerocios.

En la tabla número 1 del texto en inglés, se demuestra biométricamente que los diferentes cultivos de *Rhizoctonia*, obtenidos de pimientos y berenjenas enfermas en varios semilleros, son igualmente virulentos. Esto hace suponer que todos estos cultivos correspondan a una misma raza del patógeno.

Otros organismos del género *Fusarium* fueron también aislados. En las pruebas de patogenia estos organismos no revelaron en momento alguno estar relacionados con el desarrollo del salcocho, comportándose, por lo tanto, como meros saprófitos. Aislado ya en cultivo el patógeno, conocida su morfología y fisiología, y su comportamiento dentro de nuestras condiciones ambientales, se procedió inmediatamente a probar patogénicamente un sinnúmero de variedades de pimientos y berenjenas con el fin de determinar el grado de susceptibilidad al patógeno. En la tabla número 2 del texto en inglés se demuestra en su análisis que todas las variedades de pimientos y ajíes son igualmente susceptibles al salcocho. Las pruebas con variedades de berenjenas "Rosita," "Puerto Rican Beauty," "Pompadour" y "Black Beauty" revelaron que todas estas variedades son igualmente susceptibles a la *Rhizoctoniosis*.

En vista de que las variedades de pimientos y berenjenas no son resistentes a esta enfermedad, se hicieron varias pruebas con un sinnúmero de productos químicos con el fin de ver si alguno o varios de ellos resultaban efectivos en combatir la enfermedad.

En primer término, se dudó de la eficacia de esterilizar con vapor el terreno por dos horas a 15 libras de presión y también con formalina en dilución de una parte por 20 de agua, y aplicada esta dilución a razón de un galón por pie cuadrado de terreno. Los resultados demostraron la efectividad de estos tratamientos en evitar el salcocho.

El tratamiento del terreno con caldo bordelés 4-4-50 a razón de medio

galón por pie cuadrado de semillero, y con sulfato de cobre en la proporción de cuatro libras por 50 galones de agua y a razón de un galón por pie cuadrado de terreno, fué bastante efectivo, aunque no tan eficaz como los métodos anteriormente indicados. El caldo bordelés aplicado en la fórmula arriba indicada, después de germinar las semillas, contribuyó grandemente a evitar la propagación del patógeno a partir de brotes esporádicos de salcocho en los semilleros. Los mejores resultados en caso de brotes se obtuvieron aplicando a la zona infestada formalina en la dilución indicada.

Dada la imposibilidad de muchos agricultores de usar los métodos de desinfección del terreno mencionados anteriormente por ser bastante costosos, se resolvió probar varios polvos fungicidas de precios módicos actualmente en el mercado. Las pruebas tenían por objeto determinar el comportamiento de estos fungicidas dentro de nuestras condiciones climáticas, ya que se sabe que estos productos químicos varían en su efectividad dentro de diferentes condiciones ambientales y de acuerdo con la naturaleza de la enfermedad. Las pruebas se hicieron en tiestos llenos de tierra naturalmente infestada con *Rhizoctonia*, o, y con tierra infestada artificialmente con el mencionado organismo. De este modo se establecieron dos experimentos paralelos, uno con tierra de un índice bajo de infestación y otro con un índice alto de infestación por la incorporación de gran cantidad de micelio y esclerocios del organismo. En la primera prueba se polvorearon semillas de berenjenas con un desinfectante determinado antes de sembrarse. En la siguiente prueba 10 tiestos fueron tratados con un gramo del producto químico respectivo, para un tratamiento, por cada pie cuadrado de terreno. Cada tratamiento en las pruebas en ambos casos, tratando las semillas y tratando el terreno con fungicidas, comprendían 10 tiestos distribuidos al azar en 10 bloques distintos, bajo techo de cristal. Los resultados aparecen en las tablas 4 y 5, y según el análisis biométrico de los datos obtenidos, se llegó a las siguientes conclusiones:

1. En las pruebas en que se desinfectó la semilla antes de sembrarse, los productos "Semesan," "Z-O," "Dipdust," "Cuprous Oxide," "Corona Coppercarb," "Zinc Oxide," "Semesan Jr.," "Arasan," "Fermate" y "Spergon" demostraron igualmente su efectividad en evitar el salcocho en la fase preemergente de desarrollo de las plantas, pero fueron ineficaces todos en evitarlo después de emerger las plantitas.

2. Los productos "Dipdust," "Cuprous Oxide," "Dupont No. 1," "Zinc Oxide," "Semesan," "Spergon," "2% Ceresan," "1155-H. H.," "Fermate," "Z-O," "Arasan," "New Improved, Ceresan," "Corona Coppercarb," "Cupric Oxide," "Uspulun," "Barbak D.," "Semesan Jr.," "Cuprous Oxide," "Cuprocide" y "Bayer 1494" demostraron ser igualmente efectivos en disminuir el por ciento de infección al compararse con los datos de los testigos.

Las pruebas tienden a demostrar la eficacia de los tratamientos de compuestos de cobre y mercuriales en inhibir o quizás destruir al *Rhizoctonia solani*. Estos fungicidas son efectivos si se incorporan al terreno antes de sembrar la semilla, pero son ineficaces después de aparecer el salcocho. Podemos, por lo tanto, concluir que es una práctica muy recomendable y poco costosa la de desinfectar la semilla y también el terreno del semillero para evitar la aparición de los salcochos. De acuerdo con los trabajos de Nolla (9-11), los salcochos de pimientos, berenjenas y tomates causados por hongos de los géneros *Phytophthora* y *Pythium* pueden evitarse desinfectándose la tierra con vapor *de agua y formalina*, como hemos indicado; con "Corona Coppercarb" a razón de cuatro gramos por pie cuadrado de semillero; y también con dos aplicaciones de caldo bordelés 4-4-50 a razón de medio galón por pie cuadrado de semillero antes de regarse la semilla, seguido de otra aplicación una semana después de haber germinado la semilla. De acuerdo con los trabajos de este investigador, ningún mercurial probó ser efectivo en el combate de *Phytophthora* y *Pythium*.

En vista de los resultados obtenidos en este trabajo, podemos indicar la conveniencia de usar combinaciones de los tratamientos arriba expuestos y aplicaciones de caldo bordelés para evitar la aparición del salcocho causado por el *Rhizoctonia*, *Pythium* y *Phytophthora*.

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STUDIES ON THE AEREOBIOLOGY OF PUERTO RICO

RAFAEL A. TORO[1]

The vast and complex conglomerate of living organisms known as the biota of the air is made up of bacteria, fungi and mites. A second important group, the products of living organisms, are insect emanations, pollen grains, and the minute particles of furs, linen, feathers, animal danders, etc. which form legion in house dust. Of the biota the more abundant in the Puerto Rico air are the fungi. The present paper deals with this group.

For the last three years the writer has been studying the fungi of the air with the object of discovering if there is any relation between them and the numerous cases of nasal allergy occuring in the Island. Several facts point toward a close correlation between fungi and nasal allergy. This subject will be dealt with in a forthcoming paper.

All the fungi were obtained by exposing plates of Sabouraud's media for five minutes, in different localities, especially in the residences of asthmatic individuals. Each fungus was then grown separately in test tubes and set aside for determination. The species herein reported are those that were obtained with greater frequency. Slides coated with Brandt's glycerin-jelly were also exposed for twenty four hours, in order to obtain a daily sample of the air content and correlate the study with the quantitative and qualitative data obtained in the cultures.

The number of species of fungi herein reported is 24. Those marked with an asterisk are new to Puerto Rico, while the new species or combinations appear in bold faced type.

I wish to express my appreciation to Dr. Manuel Pila of Ponce, Puerto Rico, whose unaltered inspiration has guided this work and whose unfailing advice has been most useful. Thanks are also due to Miss Marie Betzner Morrow, of the Bacteriology Department, University of Texas, for her help in the determination of some of the fungi here mentioned.

1. CHAETOMIACEAE

1. CHAETOMIUM GLOBOSUM Kunze & Schm.

Perithecia about 300 μ in diameter, olivaceous, clothed with slender hairs; asci clavate.

Isolated from the awnings in the residence of Mr. C. E. Chardón, Mayaguez.

[1] Contribution No. 14 from the Department of Biology, School of Science, College of Agriculture and Mechanic Arts, University of Puerto Rico. Published with the authorization of the Dean.

2. PHOMACEAE

2. **Coniothyrina ponceana** sp. nov.

Pycnidiis globuloso-depressis, membranaceis, sparsis, superficialibus, nigris, contexto fuligineo; myceliis septatis fuscis, sporulis sphaeroides, fuligineis, intense olivaceis, interdum 1-guttatis; chlamydosporiis intercalaribus fuscis.

In solutionibus cultum. Prope Ponce, Puerto Rico. Oct. 1945.

Mycelium olivaceous, pellucid, septate, branched, 3 μ thick; ropy hyphae 4–6 μ wide and thick walled, darker in color; pycnidia round, black, without ostiole, membranaceous, 400–600 μ in diameter; chlamydospores intercalary, almost round, thick-walled, immersed in the substratum, in chains, dark-brown, 6–8 μ in diameter; conidia round, olivaceous, with oil drops, smooth, 4–6 μ in diameter.

The genus *Coniothyrina* was established by Sydow (Ann. Myc. **10:** 233, 1912) to replace *Coniothyrella* Speg.; which was untenable because of priority. As defined it differs from *Coniothyrium* Corda in possessing superficial pycnidia without ostiola.

Although we have placed this fungus under the above genus we do it with some degree of hesitancy. The growth in Sabouraud's medium is typically penicelloid, the mycelium presents the same type of intercalary chlamydospore we observed in some Penicillia and even the ropy masses of mycelium are sometimes observed. However, the fruiting bodies are typically phomoid and the spores round or ellipsoid, and colored.

3. MONILIACEAE

3. CEPHALOSPORIUM CURTIPES Sacc.

Colonies floccose, white; hyphae creeping, septate, branched, reverse colorless; conidiophores short, arising as lateral branches of the mycelium, conidial heads round; conidia elongate, elliptical, hyaline, 8–10 x 3–4 μ.

Isolated from room of asthmatic patient. Ponce. Oct. 10, 1945.

4. TRICHODERMA KONINGI Oud.

Colonies light green, reverse colorless, vegetative hyphae septate, hyaline, conidia elliptic, 3–4 x 2–3 μ, smooth, hyaline.

Isolated from balcony in dwelling of B. Alzamora, Mayaguez, Sept., 1944.

5. TRICHODERMA LIGNORUM (Tode) Harz.

Colonies hyaline, fruiting areas in white tufts, reverse colorless; conidiophores forming whorls; conidia globose, smooth, 3–4 μ in diameter.

Isolated from dwelling of F. Bonin, Ponce. Oct. 1945.

6. ASPERGILLUS FLAVUS Link.

Conidial areas yellowish, reverse lighter; conidiophores with pitted walls; conidia pyriform, hyaline to yellow, usually rough, 2 x 6 μ in diameter. Sclerotia white.

Isolated from dwelling of F. Bonin, Ponce. Oct. 1945.

*7. ASPERGILLUS FLAVIPES Bainier and Sartory.

Colonies white at first; then yellowish. "Hulle" cells usually present. Reverse yellow to brown, heads columnar, light colored; conidia smooth.

Isolated from parlor at Alzamora's house. Sept. 1944, Mayaguez.

8. ASPERGILLUS NIGER van Tieghem.

Colonies submerged, yellowish. Reverse uncolored. Conidial heads black.

Isolated from Dr. R. Perea's house. Mayaguez, June 1944.

9. ASPERGILLUS TERREUS Thom.

Colonies cinnamon, spreading, velvety. Reverse yellowish; heads long, up to 500 μ; conidia elliptic, smooth.

Isolated from balcony of B. Alzamora's house. Mayaguez, Sept. 1944.

*10. ASPERGILLUS LUCHUENSIS Inui.

Resembling in general character *A. niger*, but heads lighter in color.

Isolated from balcony of B. Alzamora's house, Mayaguez, Sept. 1944.

*11. ASPERGILLUS OCHRACEUS Wilhelm.

Colonies ochraceous, with little mycelium. Conidiophores pitted with yellow; conidial heads globose, radiate; conidia spinulose, yellow.

Isolated from B. Castell's house. Playa Ponce, June 1944.

*12. ASPERGILLUS TAMARII Kita.

Colonies greenish, reverse pinkish, head columnar, with radiating chains; phialides in two series; conidia pyriform, rough.

From Dr. R. Perea's house, Mayaguez, Sept. 1944.

*13. ASPERGILLUS FUMIGATUS Fres.

Colonies green to dark green; reverse yellowish; conidia dark green in mass, globose.

Isolated from parlor in home of B. Alzamora, Mayaguez, Sept. 1944.

14. PENICILLIUM CHRYSOGENUM Thon.

Colonies green, cottony, spreading; reverse yellow; conidiophores separate, about 300 μ long; conidial heads about 200 μ; conidia elliptical or globose, 3–5 μ, pale green.

Isolated from Maldonado's home, Ponce. Oct. 1945.

15. PENICILLIUM CYCLOPIUM Westling.

Colonies in coremiform masses, loose, spreading, surface blue-green, reverse reddish; conidiophores intertwined; heads in columnar masses, about 350 μ long; fructifications in three rows of metulae; conidia globose, smooth, 2–4 μ.

Isolated from M. Vallecilla house, Ponce. Oct. 1945.

16. PENICILLIUM . . . . VIRIDICATUM Westling

Colonies velvety, green, reverse colorless, conidiophores about 200 μ long;

heads in loose, radiate masses; fructifications in three stages; conidia smooth, globose, light green, 3–4 μ diameter.

Isolated from B. Alzamora's house, Mayaguez. July 1944.

*17. PENICILLIUM EXPANSUM (Link) Thom.

Colonies gray green, brown with age, floccose, concentric; reverse brown, conidiophores singly; conidial fructifications in 3 series, 120–180 μ long; phialides crowded; conidia elliptical to globose, 2–4 μ diameter, green.

Isolated from parlor of B. Alzamora's house, Mayaguez, July 1944.

18. PENICILLIUM RUGULOSUM Thom.

Colonies yellowish-green, reverse yellow to orange, conidiophores about 200 μ; conidia elliptical, green, verrucose 3–4 x 2.5 μ diam.

Isolated from parlor of R. Perea's home, Mayaguez, June 1944.

*19. SCOPULARIOPSIS BREVICAULIS Bainier.

Colonies white at first, then yellowish brown; conidiophores short; conidia in chains, pear-shaped, in mass light brown to chocolate, 6–8 x 7–9 μ.

Isolated from parlor of Maldonado's house, Ponce. Oct. 1945.

20. ACROSTALAGMUS CINNABARINUS Corda.

Colonies round, orange to red; conidiophores terminating in branches bearing conidia; conidia oblong, 5–8 x 3–4 μ; head enveloped by slime.

Isolated from Bauza's parlor, Ponce. Oct. 1945.

21. TRICHOTHECIUM ROSEUM Link.

Colonies white at first, then pink; conidiophores erect, conidia acrogenous, single; forming a head by the apical growth, cell larger, pear shaped, two celled, hyaline, 19–14 x 8–10 μ.

Isolated from porch at Alzamora's house. Mayaguez, Sept. 1944.

4. DEMATIACEAE

22. STACHYBOTRYS ALTERNANS Bonorden

Sterile hyaphae black brown; conidiophores erect, unbranched; conidia borne on phialides, elliptical, black, echinulate, 8–12 x 5–8 μ.

Isolated from Maldonado's room. Ponce, Oct. 1945.

*23. HORMODENDRUM CLADOSPORIOIDES (Fres) Sacc.

Colonies dark olivaceous, round, dense; conidiophores erect, branched, olivaceous at the apex; conidia cylindrical to oval, smooth, olivaceous, continuous or septate.

Isolated from sputum and bed-room of Tuti Alzamora, Mayaguez, June 1944.

24. **Curvularia pilae** sp. nov.

Hyphis sterilibus tenuibus, effusis, flexuosis nodulosisque, septatis atrofuscis; conidiophoris erectis rigidis fuscis; conidiis obtuse-fusoideis, 2–3 septatis, fuscis, loculo centrali obscuriore dilatati ibique plerumque abrupte geniculatis, loculis terminalibrus dilutioribus subhyalinis.

Curvularia lunata (Walker) Boedjin valde affine, sed conidiis minoribus diversum.

Eximio medico portorricence Emmanueli Pila, sui libenter diccata.

In solutionibus cultum. B. Alzamora #4 (*typus*) Prope Mayaguez.

Mycelium septate, richly branched, subhyaline to dark brown; hyphae 3–7 μ wide, sometimes nodulose; conidiophores brown, septate, erect, unbranched, dark brown on the lower part, in the upper, lighter and pellucid, sometimes swollen and with knobs, lower cells 6 μ wide, 8 μ long, tip cells narrower, nearly round, 4 μ in diameter, tips obtuse, 190–280 μ long; conidia borne in a whorl at the tip of the conidiophores, two to three septate, straight or curved, brown, end cells light colored, center cell dark-brown, 15–20 x 6–9 μ, ends obtuse.

The genus *Curvularia* was established by Boedjin (Bull. Jard. Bot. Buitenzorg **13:** 120, 1933) by segregating from *Helminthosporium* Link those species characterized by short, few septate conidia. In addition to the number of septa, a feature of the genus is the curved or bent character of the conidia, due to the growth of the central cell, which becomes larger and darker than the terminal cells. This makes the spores dark brown in the center and almost hyaline in the ends. This same character of the spores is a feature of some species of *Spondylocladium* Martius and *Acrothecium* Preuss.

NOTES ON TRETANORHINUS OF CUBA AND THE ISLE OF PINES

By CHAPMAN GRANT

INTRODUCTION

The first specimens of *Tretanorhinus* I had ever seen were those I described from Grand Cayman. The question was whether they were closer to Cuban or mainland forms. The key of Duméril and Bibron, Vol. 7, p. 349, showed that they were closer to the Cuban form. Dr. Barbour kindly sent me a Cuban specimen which he said was a "good typical example." When this specimen arrived it was seen to differ in color and pattern from the Grand Cayman specimens which I described (Grant, 1940, p. 46) as "differing in pattern and color only" from the Cuban form. While the Cayman paper was in press, Mr. Adrian Vanderhorst arrived from Cuba with a small herpetological collection. He presented me with his only specimen of *Tretanorhinus,* which was indistinguishable from the Cayman form except for color differences. Since Barbour and Ramsden (1919, p. 193) say that "this species is remarkably uniform in colouration . . . ," I decided that there must be more than one species in Cuba of which they had seen only the one with uniform coloration. I had been planning another collecting trip to the Antilles and this prompted me to visit Cuba. At about this time I heard of Congdon Wood's paper (1939) on this topic. Close reading of his paper made it clear that there was still something to be learned. The trip was cut short by the beginning of the War, but I was nevertheless able to collect the series of 59 specimens which is treated herein. The series was taken on the property of the Central Soledad near Cienfuegos, Santa Clara, Cuba, from January 13–23, 1942.

The material available at present in museums is insufficient to satisfactorily delimit subspecies. Mr. Wood's classification was largely based on color and markings, which might have been sufficient if his series had been large. The establishment of a subspecies based on the color of four specimens is hardly convincing, especially when some of the material in museums was originally preserved or set in formalin. Specimens frequently have insufficient ecological data. For instance, all of my series were taken on the Soledad properties in fresh water streams except one which was taken in a tidal estuary. This one brackish water specimen represents a separate species. The average label would not have differentiated the environment of this from that of the others, nor would the catalogue necessarily have made the distinction.

Probably one or more species and or several subspecies of *Tretanorhinus*

inhabit Cuba and the Isle of Pines. When the problem is carefully worked out, the boundaries will doubtless coincide with ecological factors more than with the present vague geographical divisions.

Possibly some modification in nomenclature should be made in Wood's review of the genus in Cuba and the Isle of Pines. Wood uses preoculars, number of scale rows, light or dark venter, spots or crossbands as diagnostic characters. I endeavor to show that in my series, variation in preoculars and spots and bars are largely sexual manifestations and that the color of the venter is individual.

SYNONYMY

T. insulae-pinorum Barbour, probably a synonym.

Probably *T. insulae-pinorum* Barbour, is a synonym of *T. wagleri* (Jan), both being 21 scale row snakes. Barbour (1916, p. 306) gives the two following contradictory descriptions:

> "*Tretanorhinus insulae-pinorum*. sp.nov. This species differs from the Cuban *T. variabilis* in having regularly 21 instead of 19 rows . . . I have examined 3 examples . . . The series of 9 Cuban examples . . . have 19 rows . . . There do not seem to be other differences in squamation and the color is the same so far as one may judge from Mr. Link's material preserved in formalin. . . ."

Barbour reverses this diagnosis (1937, p. 154):

> "This species [*T. variabilis insulae-pinorum*][1] seems to have regularly 19 rows of scales while the Cuban snakes have 21. This is, at first sight, a trivial character but one which is apparently really diagnostic."

Wood (1939, p. 7) lists M.C.Z. No. 12,285, *T. v. insulae-pinorum*, as having 20 scale rows. I would have expected that it was really a 21 row snake since an even number of rows is not normal in this species. Mr. Loveridge kindly checked and reported that it had 19 rows. This individual may be an exception, abnormal, a specimen of another species or the labels may have become mixed. This is discussed later.

In Cuba there are snakes with 19 and 21 scale rows, which might account for Barbour's change of diagnosis, but I believe that the original description giving 21 rows is probably correct for the Isle of Pines freshwater population.

Tretanorhinus variabilis wagleri (Jan)

1865 *Helicops wagleri* Jan, Arch. Zool. Anat. Phys., Vol. 3, p. 247: Icon. Gen., Vol. 28, pl. 1. fig. 1, 1868.

[1] Barbour reduced his *T. insulae-pinorum* species to subspecific rank not because of any additional evidence of intergradation, but, as he says, merely to designate relationship.

1916 *Tretanorhinus insulae-pinorum* Barbour, Ann. Carnegie Mus., Vol. 10, pp. 306–307; Zoologica, Vol. 11, p. 110, 1930; idem. Vol. 19, p. 134, 1935; and Loveridge, Bull. M.C.Z., Vol. 49, p. 351, 1929.

1937 *Tretanorhinus variabilis insulae pinorum* Barbour, Bull. M.C.Z., Vol. 82, p. 154.—Wood, Proc. New England Zool. Club., Vol. 18, p. 6.

1939 *Tretanorhinus variabilis wagleri* Wood, Proc. New England Zool. Club., Vol. 18, p. 7.

Type.—Unknown to writer.

Diagnosis.—A fresh water form from the Isle of Pines and western Cuba, intergrading at some place or zone with *T. v. variabilis*. Females usually, and possibly constantly, with 21 rows; tail as much as 10 caudals longer than in *variabilis variabilis*; color pattern with possible minor differences.

Tretanorhinus variabilis variabilis Duméril & Bibron

1854 *Tretanorhinus variabilis* Duméril & Bibron, Vol. 7, p. 349, pl. 80, fig. 4.—Cope, Proc. Acad. Phila., p. 298, 1861; idem. p. 309, 1868.—Jan, Arch. Zool. Anat. Phys., Vol. 3, p. 254, 1865.—Gundlach, Erp. Cub., p. 80, 1880.—Bocourt, Le Natur., p. 122, 1891.—Boulenger, Cat. Sn. Brit. Mus., Vol. 1, p. 282, 1893.—Barbour, Mem. M.C.Z., Vol. 44, p. 330, 1914; idem. Vol. 47, pp. 192–194, 1919; Zoologica, Vol. 11, p. 110, 1930; idem. Vol. 19, p. 134, 1935.

1861 *Tretanorhinus cubanus* Gundlach, Mon. Berlin Ac., p. 1001; Erp. Cub., p. 81, 1880.—Bocourt, Miss. Sci. Mex. Rept., p. 795, 1895.

1865 *Tretanorhinus variabilis* var *adnexus* Jan, Arch. Zool. Anat. Phys., Vol. 3, p. 247.—Bocourt, Le Natur., p. 208, 1891.

1883 *Helicops variabilis* Garman, N. Am. Rept., p. 33.

1937 *Tretanorhinus variabilis variabilis* Barbour, Bull. M.C.Z., Vol. 82, p. 154.—Wood, Proc. New England Zool. Club., Vol. 18, p. 9, 1939.

1939 *Tretanorhinus variabilis adnexus* Wood, loc. cit., p. 8.

Type.—Paris Museum.

Diagnosis.—A fresh water form from the eastern part of Cuba; 19 scale rows counted behind neck; subcaudals, male not over 70, female 54; color similar to *T. v. wagleri*; intergrading with *wagleri* at an undetermined place or zone.

Tretanorhinus gaigeae sp. nov.

Type.—Male, No. 60 Grant Cuban Coll., C. Grant coll., in brackish tidal estuary at Rancho Gavilan, Cienfuegos, Cuba; Jan. 18, 1942; adult male.

Diagnosis.—Upper parts light gray; 19 scale rows counted behind neck; small dorsal spots or saddles instead of crossbars as in *variabilis*; a con-

tinuous dark line between ventrals and first row; first, second and part of third rows cream color; a broken black line on upper part of third row; above this, gray. Color and markings not approached by any specimen in a series of 58 specimens of *variabilis*.

Description.—Squamation as in *v. variabilis*; ventrals 154, caudals 68, preoculars 2–2, loreals 1–1; body 581 mm., tail 175 mm.; belly cream colored, finely speckled with brown; 34 dorsal spots neck to sacrum, about 20 on tail.

Wood says of M.C.Z. No. 12, 285: "Nueva Gerona, is gray, with crossbars for the most part broken into small spots, resembling the mainland *nigroluteus* in this respect. Dark lines on first and fourth rows, the latter broken into spots posteriorly. Second and third rows cream colored. Below brown, speckled with white. Upper half of rostral, internasals, prefrontals and temporals light cream colored. Frontal dark brown; parietals light brown, finely speckled with black. This specimen with its extremely odd color pattern and unique scalation is probably no more than a freak."

Both specimens are males and it is possible that the female has 21 scale rows. Dr. Dunn examined my No. 60 and said that he was impressed with the difference in color.

DISCUSSION OF *Tretanorhinus v. variabilis* D. & B.

Habits

At the time of my visit to Cuba, Dec. 13–23, 1941, it was very dry. Many of the smaller streams were a succession of puddles swarming with small fish which were being preyed upon by birds, crabs and snakes. The snakes were in turn being mutilated and even killed and eaten by the crabs. Many snakes were taken which had old or fresh scars on various parts of the body. The snakes come out of hiding about an hour after dark and start hunting fish. Snakes taken as late as 10 P.M. contained little food, but those found in the mornings resting on the mud under rocks or debris were full of fish. The snakes are quiet, easily caught and make no attempt to bite, but once frightened they show great agility in hiding. When taken by hand one characteristic is at once noticed at variance with the habits of most snakes: they grasp one's wrist with their tails with considerable force. A specimen can hold up the weight of its body if its tail is allowed to grasp one's finger. The nocturnal habits of this snake are attested by the vertically elongated pupil. There were no enlarged ova, but the knobbed scales on head, neck and region of the vent of males were prominent, a modification which is apparently permanent after maturity.

Barbour (1914, p. 330) says "It is a strictly aquatic snake which never leaves the water. . . . It is a difficult species to find." (1916, p. 306) "The catibo leads a colorless existence . . . The members of this genus are the

most strictly aquatic reptiles I know, quite equalling the Hydrophids in this respect. I have never heard of their eggs being found, and I have often wished I knew whether they come ashore to lay. I presume that they do."

Scale Rows

Serpents have probably undergone a general reduction in the number of body rows through modification of the body itself while evolving from a lizard-like form. The head of the snake is therefore the most logical place to look for remnants of lost rows since it has changed less than the body. Every neck scale or scale bordering the head-plates may have some significance although not always possible of interpretation. On the other hand there are cases among serpents where the number of body rows has increased with an increase of body size. This reversal of the general evolutionary trend is to meet some obscure mechanical law correlating the size of the scale and consequently the number of rows to the size of the snake. The correlation varies in different genera also due to obscure reasons connected with ecological factors and physical characteristics or manner of locomotion of the genus. *Typhlops* reduces by dropping a ventral row next the center; an indication of the order in which other serpents have lost their midventral suture. In the case of divided anals or preanals in *Tretanorhinus* the preceding ventral projects an angle posteriorly in an attempt to cover the suture. When a snake is found to have more rows at midbody than at the anterior part of the body it is probable that a short neck row occupies the same relative position as the added row.

Dr. Dunn points out that the hooded cobra's numerous neck rows may be a result of the hood and not representative of primitive body rows.

I have elsewhere (Grant, 1937) discussed the probable non-existence of a "midventral" row in reptiles except in snakes. The middorsal row may have had a different origin from the body rows. It may have originated with callosities, scutes or spines covering the vertebral processes as is now seen in the crests of lizards. It possibly did not develop from a fusion of the two highest body rows. The spiny crests of lizards are usually interrupted or reduced at neck and sacrum as is the spinal or vertebral row in snakes.

Ruthven (1908, pp. 16–21) found that the first rows to be dropped in *Thamnophis* were about midway between the ventrals and the spinal and were dropped in a fixed order somewhere near the middle of the body. Blanchard (1921, p. 10) stated that *Natrix* did the same.

Tretanorphinus, however, drops the paravertebrals at about the 100th ventral plus or minus ten, but apparently without dropping the fourth or fifth rows.

I have written on the origin of the rows on the head of *Natrix* (Grant, 1935, p. 927) pointing out that frequently two rows start at the juncture of the parietals and extend only a short distance when the spinal or vertebral row appears. The spinal row does not appear to be a fusion product of the two dropped rows (see fig. 1.). Thus the paravertebrals are dropped by all three genera, but at widely different places.

Natrix and *Thamnophis* drop rows 4, 5 and 6 in a fixed order at about midbody. There is no such reduction apparent in *Tretanorhinus* until the neck is examined when it is seen that there is a short fourth row which

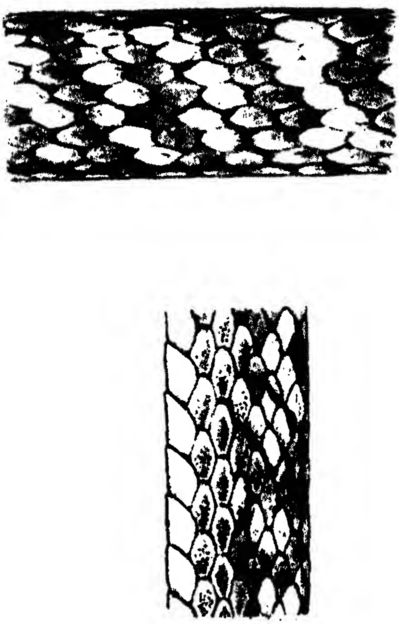

FIG. 1. Squamation of head of *Natrix sipedon* showing origin of scale rows.

stops at about the twelfth ventral. Thus the three genera seem to drop the same rows, but at widely different places.

To recapitulate: *Natrix* shows rudimentary paravertebrals and drops fourth etc. at about midbody. The "19 row" *Tretanorhinus* drop the paravertebrals at about midbody and the fourth row is rudimentary. Therefore one might expect to find that the "21 row" *Tretanorhinus* extended the 4th row to about midbody.

The very first 21-row snake examined from the U. S. N. M., No. 27,980 carried out this expectation. The 4R drops at 72 and the 4 L at 18. This seemed to show a direct similarity between the genera in this respect, ex-

cept for the fact that all the other U. S. N. M. 21-row specimens examined did no such thing; they drop the 10th and 9th rows.

This brings up the possibility that larger series may prove that there are two species; one dropping the 10th and 9th and having a rudimentary 4th and another species which drops the 10th at midbody and the 4th also at midbody.

My Soledad series are all 19-row snakes as commonly understood. However, all can be termed 21-row snakes if the rudimentary 4th row which extends to about the 12th ventral be counted. They then could be termed 21-19-17 row snakes, but by present usage they are all 19-17 row snakes since a rudimentary or midbody row is seldom noted. This fact shows the advisability of giving the first count as the maximum midbody count and so stating or explaining definitely any other system used.

Dr. Dunn has this to say: "It is a general characteristic of Xenodontine snakes to reduce from midbody by dropping paravertebrals; of Natricine and Colubrine snakes to reduce from midbody maximum by dropping laterals. There is lots of evidence as to this in many genera and species. What happens on the neck is as yet not widely known, nor for many forms. It would be interesting to know more and the odd U. S. N. M. 27,980 is interesting."

Scale rows of the U. S. N. M. specimens

Disregarding the short neck rows it will be remembered that the Soledad series dropped the 9th row at 100 plus or minus ten. The 6 U. S. N. M. 19-row specimens drop the 9th or paravertebral row at from the 90th to the 123rd, averaging 111. The six 21-row specimens present an entirely different picture. Instead of having an extended 4th row as one might expect, the 10th and 9th rows are dropped, the 10th at from the 52th to the 87th, averaging 71; the 9th at from the 116th to the 142nd, averaging 130. Two of this latter six were irregular. No. 27,499 has irregular rows that appear and disappear in a most confusing way. In places this specimen can be counted as a 23 row snake. I have seen such examples in *Natrix*.

There may be two species of 21-row snakes; one with extended fourth row which drops at about midbody and the 10th somewhat farther back; another species which drops the 10th and 9th. If these two forms do exist the female of each may be a 21-row and the male a 19-row form.

Errors possible in counting rows

The spinal row starts several scales behind the parietals and disappears a few scales anterior to opposite the vent. A count just anterior to the vent might result in an even number which would not be a true count. Occasionally there is a short row near the vent between rows 2 and 3 or 3 and 4, which, if counted would give a count of two too many. Frequently

a row is dropped as much as 10 scales anterior or posterior to its mate on the opposite side. This usually accounts for the even-number counts frequently seen. The writer remembers one *Natrix* in which a row on one side was represented only by two small scales and a third which appeared at a short distance.

An example is U. S. N. M. 27,980. Wood lists this snake as having 20 rows. This snake drops the 4R at 72, the 4L at 18; 10 R & L at about 129. Thus it has 21 rows from 1 to 18; 20 rows 18 to 72; 19 rows 72 to 129; 17 to vent. Loveridge calls it a 21-row snake; Dunn (letter Nov. 24, 1944) and Dr. L. M. Klauber call it a 19-row snake with an abnormally long 4R.

Since the "usual counting place" is half way between snout and vent, when a species of snake having a spinal row counts out an even number, the cause should be discovered and the explanation given. An even number is probably caused by an abnormality.

DATA ON SOLEDAD AND U. S. N. M. SPECIMENS

Size and proportions

The females appear to be larger judging by this series and the Cayman Island species. The tails are proportionately shorter than the males and the young have tails proportionately shorter than the adults.

Secondary sexual differences

Males are smaller, have shorter bodies with fewer ventrals; longer tails with more caudals; predominate with a single loreal; have greater proportion of preanal sutures; have heavier keels and striations and when mature have knobs on chin scales and near vent. The female has a greater proportion of 3 preoculars and has more acute abnormalities than the male.

In all specimens recorded by Wood every one with 21 rows or with preoculars 3-3 is a female, but he does not stress this fact. The only specimen Wood lists with 21 rows that he does not list as a female is his p.8; "U. S. N. M., No. ?, 21 rows, sex ?" Miss Cochran kindly furnished the number as 27,499 and the sex, female.

The anal and preanal

The anal and frequently the preanal is divided by a diagonal suture running forward from the snake's right to left. The direction of this diagonal in this species is invariable (Grant, 1944). There is occasionally a half ventral entering from either side immediately anterior to the anal or preanal or between the two.

The anal region is modified in 58% of males and only 16% of females. This discrepancy seems to have a direct sexual significance and might be considered in the category of secondary sexual dimorphism. The 12 U. S.

N. M. specimens examined had no divided preanals, but only two were males.

A divided anal, preanal or a half ventral in this region is preceded by a pointed ventral, the point tending to protect the suture. This may be an indication of how important for survival it was for snakes to develop single ventrals.

Males with split preanals seem otherwise normal, but one of the two females thus split seemed to be generally abnormal, having abnormal loreals and temporals and she was the only specimen in the whole series with three postoculars in addition to having an extra half ventral.

Certain scales nearly free from abnormalities

The frontal, prefrontals, internasals, parietals, rostral, mental and chin shields show practically no abnormalities. In two cases the corner of the prefrontal enters the orbit and this might be considered as a fusion of that scale with the preocular. The posterior angle of the frontal is subject to considerable variation in outline. The supraoculars occasionally seem to fail to pinch off the uppermost preoculars on one side.

Scale abnormalities

Head abnormalities are more numerous in females. Omitting the labials there are 26% male and 60% female abnormalities; including labials there are 60% male and 180% female abnormalities. The term "abnormality" used here could be supplanted by "unusual" or in some cases "supernumerary".

Individual variations in tabular form

	34 males	25 females
Loreals....	1–1, 1–2, 2–2	1–1, 1–2, 2–2, 2–3
times occurring..	23 4 7	10 5 8 2
Preoculars	1–1, 1–2, 2–2, 2–3, 3–3, 4–4	2–2, 2–3, 3–3, 4–4
times occurring..	1 1 8 11 12 1	4 1 19 1
Ventrals...	150, 1, 2, 3, 4, 5, 6, 7, 8, 9, 160, 1, 2, 3 1 1 1 2 9 5 3 4 4 3 0 0 0 1	156, 7, 8, 9, 160, 1, 2, 3, 4 2 0 6 3 4 4 1 2 3
Caudals...	2 broken not counted 60, 1, 2, 3, 4, 5, 6, 7, 8, 9 1 6 8 5 4 2 3 0 2 1 average 63.5; range 9	4 broken not counted 48, 9, 50, 1, 2, 3 1 4 7 4 1 4 av. 50.7; range 5

Note actual gap of seven counts between sexes in caudals and that females have more ventrals and fewer cuadals.

Labial variation

Small triangular scales are wedged between the lip-corners of certain labials. Their shape and position give no clue that they were derived from either of the adjacent labials. Normally there are 8 upper and 10 lower labials. Of 34 males 9 had 11 irregularities; of 25 females 13 had 32; 26% males and 52% females had irregularities; irregular males averaged 1.22 irregularities; females, 2.46. Nearly 50% of irregularities were between the 4th and 5th lower labials.

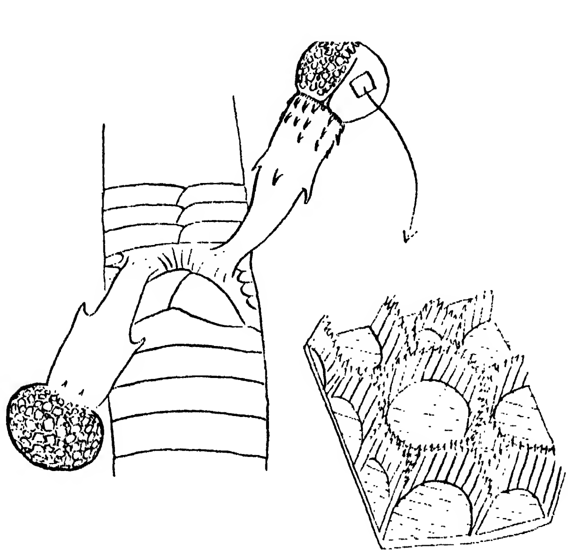

FIG. 2

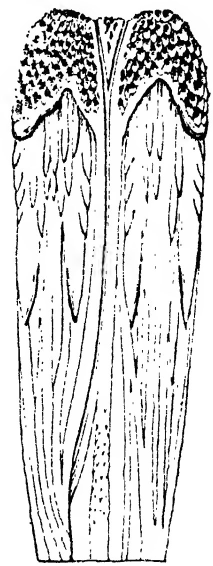

FIG. 3

FIG. 2. Hemipenes of freshly killed *Tretanorhinus v. variabilis*, injected.

FIG. 3. Hemipenes of *Tretanorhinus v. variabilis* drawn from a dissection, after Cope, Report of U.S.N.M., 1898, Plate 23, fig. 11.

Hemipenis

The drawing of the hemipenis herewith was made from specimens in which the organ was injected with alcohol immediately after death. This engorges the organ to such an extent as to hide the sulcus. (Fig. 2). Cope's fig. 11 of plate 23, shown as Fig. 3, was probably made from a dissection. Each figure shows characters not shown in the other.

Color pattern and variation

The venter ranges from cream through various degrees of pigmentation to almost solid slate in different individuals. The dark color displaces the light by dendritic patterns. There is a dark or nearly black line at the

juncture of ventrals and first row. This line may not be apparent when the venter is dark. A light band occupies the remainder of the first, all of the second and part of the third rows. This band may be greatly reduced by pigmentation or may be chocolate. From the upper part of the third row the true dorsal pattern begins. Fundamentally it consists of about thirty cross bars nape to vent; twelve on tail. The bars occupy one to three

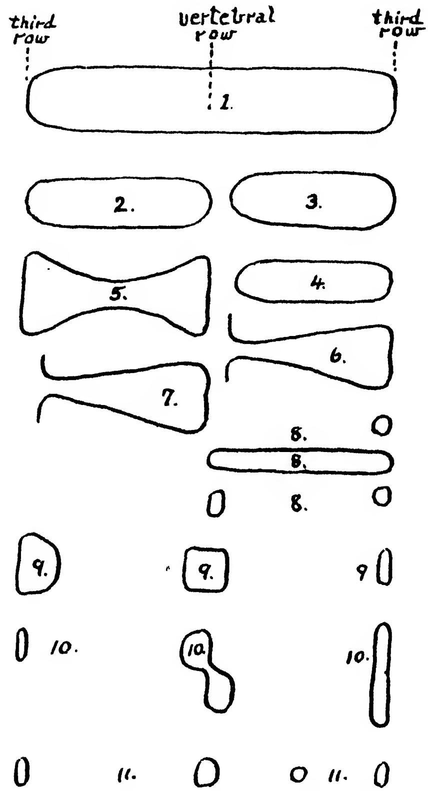

FIG. 4. Diagrammatic drawing of the various color patterns found on *Tretanorhinus v. variabilis*.

scales in width, separated by three to five scales; bars are occasionally outlined by light and there may be false shadow-bars between them. No specimen has been seen that adheres to any one dorsal pattern for its entire length. The most common variation is for the pattern on the two sides to alternate. Considering the bars on one side: they may narrow at the middle and widen at the ends becoming hour-glass shaped; they may separate, the upper part remaining a spot or coalescing with its mate on the

opposite side forming a saddle; the lower part may remain a spot, but it usually forms a dash of various lengths and in one case a continuous wide stripe; the spots and bars may alternate; the spinal may be clear or have an occasional fleck or it may be black and the bars may touch it or not; the pattern may be reduced to occasional flecks on spinal, mid-side and third row. There may be combinations of these patterns on various parts of the body, but the predominately spotted patterns are confined to the males.

It is not a simple matter to count the bars from neck to sacrum. It is doubtful whether two students would obtain the same counts in a series of specimens.

As is to be expected, the pattern is more clearly defined on young specimens, but does not change in any way with growth. It does become obscured to varying degrees by added pigment. Another change that comes with maturity in many cases is a chocolate pigment which appears on the first three rows or the lateral stripe. The background is rarely chocolate.

Patterns expressed in their simplest terms, by sexes, taken at the vicinity of the 100th ventral:

Pattern	male	female
1. simple bars	8	8
2, 3, 4. bars, spinal clear	0	1
5. hour-glass	13	12
6. bars, spinal black	2	1
7. bars, third row black	1	0
8. bars and spots alternating	1	3
9. saddle and dash or spot	2	0
10. spot and dash	6	0
11. dots only	1	0

Dr. Oliver kindly read this MS and challenged this sentence by saying; "Isn't obscurity a change?" Yes, obscurity is a change in degree of pigmentation, but my meaning is a change in pattern such as spots growing into bars etc. during growth of the individual.

As to patterns I believe that possibly the primordeal coloration of many animals was a plain dark dorsum grading into a lighter venter. This is the simplest pattern and could be considered to consist of two longitudinal stripes—an upper and a lower color. This pattern gradually became more complicated and in turn the more numerous stripes broke up into checkered patterns and these in turn coalesced into cross bars by the process of natural selection. I do not believe that a pattern ever migrates on an individual. Slow moving snakes and animals and/or the young of fast moving adults may be spotted or barred. In the first instance the bars are permanent; in the second they are retained while useful. A pattern

that fades out is usually replaced by a solid color, but in the case of *Sphaerodactylus cinereus* Wagler, the cross bands of the young are replaced by fine dots on a gray ground. The design has not migrated; it faded out and was followed by another. In some sexually mature male *Pseudemys* sp. we find a migration of dark pigment towards the sutures leaving the centers of the scutes light. Again it is not a pattern migration since the true pattern of ocelli, when present, does not move or change other than to fade. Neither do we consider this last case to be melanism as Barbour chooses to call it; melanism being congenital.

Dr. Dunn states in letter 11/24/44; "The general opinion is that spotted pattern precedes striped or ringed or uniform color in development and in phylogeny (cf. Zenneck, Zeichnung der Boiden). I do not wholly subscribe to the general opinion, but I have seen spotted young change into uniform adults and spotted young change into striped adults, and spots in the embryo which are stripes at hatching. It certainly happens in development. I refer specifically to *Elaphe quadrivittata, Lampropeltis rhombomaculata* and *Leimadophis bipraeocularis* (whose 11 month development in the egg I followed in Bogota). The question is whether development implies anything as to phylogeny as general opinion says it does?"

Dunn does not make it clear whether he refers to the disappearance of a pattern which is followed by another, or whether there was a true migration of a pattern or part of a pattern.

The color patterns of my series may be expressed sexually: males have about 70% barred and 30% spotted pattern whereas the females are 100% barred. The male venters are 26, 53 and 21% light, medium and dark respectively whereas the females have 28, 64 and 8%. There is a natural correlation between spotted pattern and light venter; the spotted pattern requiring less pigment than the barred patterns.

Migration of pattern with growth was considered by Barbour who says (1919, p. 193): "In the young also the dark cross bands appear as oblong or squarish dorsal patches which become extended into strap-like bands with increasing age." I have four very young specimens which bear the entire strap-like bands and not the squarish dorsal patches, and adults which bear the squarish dorsal patches. I know of no snakes in which the markings spread with growth. In this and many other species the pattern tends to become dim or almost obliterated by an increase of dark pigment, but the basic pattern remains unchanged. In the common blue racer, *Coluber* sp., the young have a pattern of cross bars which fade out as the snake grows, but the pattern does not change shape or move.

On the same page Barbour quotes Boulenger as saying: "... a more or less distinct light lateral streak on the second and third rows of scales ..." to which Barbour replies: "The white lateral band, he mentioned is always found in the young, but we have never observed it on adults."

In three of my young specimens the band is distinct and in the fourth dim. Among adults it is occasionally distinct, but usually dull or obscured.

Dr. E. R. Dunn on *Tretanorhinus*

Dunn 1939, writing on the mainland forms says; "The Antillean forms are the subject of a separate report by Mr. G. Congdon Wood, but I have examined the material with him and each of us has had access to the findings of the other.

"For the genus as a whole three groups can be made out. These differ in range, in markings and in ventral count as shown below:

	Atlantic drainage, mainland	Antillean	Pacific drainage, mainland
Dorsal markings	two rows of dots	crossbars	three dark stripes
Male ventrals	133–139	152–162	166–169
Female ventrals	138–151	154–168	168–177."

My Soledad series agrees with Dunn's ventral counts being, males, 150–163, females 156–164.

Congdon Wood on *Tretanorhinus*

Some of the data in Wood's paper seemed out of line with the Soledad specimens. Dr. Barbour kindly forwarded me under date of June 9, 1942, data which Mr. Loveridge had been kind enough to look up. Dr. Cochran kindly loaned me 12 specimens which seemed to have inexplicable data. Mr. Charles Shaw, who has done much counting and sexing for Dr. Klauber, kindly sexed the U. S. N. M. specimens, as I wanted corroboration in making any corrections in Wood's paper.

Some of Wood's data which seemed unconvincing were apparently wrong as shown below. Three cases of sexing which he omitted are supplied.

Specimens		Wood's data	Loveridge's data
M.C.Z.	12,285	20 rows	19 rows
	7,932	female	male
			sexes by Shaw
U.S.N.M.	27,980	sex ?, rows 20	female, 21 rows
	59,322	sex ?, V.?, C.?	female, V. 161, C. 70
	56,367	loreals 1	loreals 3–1 or 2–1
	56,362	male	female
	83,318	C. 67 plus	C. 57 plus
	27,499	sex ?, V.?. loreals 1	female, V. 160, lor. 2–1.

Wood uses trinomials in his synonymy in quoting original descriptions where a binomial was used by the author.

Some of Wood's data which seemed out of line are correct. His specimens seem to have about ten more caudals than the Soledad series; spotted females; fewer abnormal scutes; more scale rows.

The characters which Wood uses as of subspecific value are; (1) color of venter, light or dark; (2) 2 or 3 preoculars; (3) spots or crossbars; (4) 19 or 21 scale rows.

The Soledad series shows the light or dark belly to be purely an individual variation and I believe that it is probably so in other localities. The matter of 2 or 3 preoculars seems to have a sexual significance in all specimens listed by Wood as well as the Soledad series. I attribute the predominance of 3 preoculars in females to the fact that they are the larger sex and heavier headed. The Soledad series seemed to show that spots were strictly a male pattern, but the U. S. N. M. specimens seen by me seem to disprove this assumption. Larger series are needed to settle this point. 19 or 21 scale rows is apparently diagnostic and it would be of interest to know whether a large series would still show the 21 rows confined to females. Data showing where 20 and 19 row populations intergrade would be of value in defining subspecies.

Every specimen in Wood's paper with 21 rows is a female; every specimen with preoculars 3-3 is a female.

Dr. Dunn Nov. 24, 1944 writes; "Wood described no new forms, but made a tentative allocation of a number of existing names. Your big Soledad series has pretty much eliminated his ventral color characters and his preocular characters. There is left the occurrence of 21 scale rows in the west—nearest to 21-row *nigroluteus* of the mainland—and perhaps more spotting and less crossbarring in the west—nearest to the never-barred *nigroluteus* of the mainland. He helped open the situation for discussion by showing that 21 row snakes were not confined to the Isle of Pines, but also occured in Pinar del Rio."

SUMMARY

Little is known about *Tretanorhinus* from Cuba. Individual variation is so considerable that a large series and extensive collecting will be necessary before any definite picture can be formed.

It appears that the number of caudals, pattern, color, preoculars, number of scale rows and possibly the sequence in which the rows are dropped have either taxonomic or sexual significance or both.

There probably is a salt or brackish water form common to Cuba, the Isle of Pines and surrounding islets. This form is probably at present represented in museum collections, but unidentified. The fresh water form has doubtless speciated considerably. The genus seems to be very plastic.

From our present knowledge the following forms appear to be recognizable:

T. v. wagleri (Jan): fresh water of the Isle of Pines and western Cuba; a long tailed form with 21 scale row females; ten more caudals than *T. v. v.*

T. v. variabilis D. & B.: fresh water from eastern Cuba; 19 rows; caudals male 70, female 54.

T. gaigeae, sp nov.: a light gray spotted form, probably confined to brackish water.

ACKNOWLEDGEMENTS

Dr. L. M. Klauber was generous with his library and his time; Mrs. H. T. Gaige and Dr. James A. Oliver read the MS and gave valuable advice; Dr. E. R. Dunn went over the MS painstakingly and gave much valuable help; specimens were kindly loaned by Dr. Thomas Barbour and Dr. Doris Cochran who also furnished data on other specimens; Mr. Loveridge also furnished some much needed data. Mr. Charles Shaw kindly sexed some specimens.

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A NEW NAME FOR *ALSOPHIS ANTILLENSIS*

By CHAPMAN GRANT

Schlegel (1837) described *Psammophis antillensis* from St. Thomas, Guadeloupe, Martinique and Cuba. Brongersma (1937) revised this composite species, but left a few loose ends which this paper endeavors to catch up.

The *Alsophis* which inhabits most of the islands and islets east of Puerto Rico has long been known as *Alsophis antillensis* (Schlegel). If a sufficiently large series of specimens could be assembled from each islet of this area, an average difference, possibly of subspecific value, between many of the populations would be apparent. The large series which I have collected from some of the islands tends to bear this out (Grant, 1932). On the other hand, many specimens from most of these localities could be matched in a large series from almost any other island in his area.

Color pattern has played an important part in the taxonomy so it may be advisable to explain how Stejneger's fig. 174 came to be considered typical of the pattern of *antillensis*.

Stejneger habitually described a single specimen of a species in detail and then discussed variations in a separate paragraph. When he summarized *Alsophis antillensis* (Stejneger, 1904; p. 704 et seq.) he had material from St. Thomas, which was one of the type localities, but these specimens were not in good condition. Therefore he selected a half-grown, distinctly patterned specimen from Culebra Island, USMN No. 25557, and illustrated its color pattern at midbody with his Fig. 174 (see cut). He did not state that this pattern was typical of the species. He merely remarked that the marking on the fifth scale row appeared to be constant, but did not state how far it extended posteriorly, nor did he mention the pattern depicted on the eighth row in Fig. 174. He said: "On the whole the coloration is much as in the specimen described above. . . ." The specimen "described above" was not the one figured, but No. 25554, an adult, doubtless with a dimmer pattern than that of the half-grown specimen figured.

I have found in well-preserved material from the Virgin Islands area that the pattern on the eighth row is usually wanting and the pattern on the fifth may not extend beyond the region of the neck. Anteriorly the pattern on the fifth row may be duplicated on the sixth row and an inverted pattern may be found for a short distance on the fourth row. Note that the fourth row is dropped at about the 108th ventral, or posterior to the middle of the body. If the pattern extends beyond this point it appears to occupy the fourth row, but it is in reality on the same row on which it originated

the fifth. In my observation a one row pattern does not switch from one row to another.

Stejneger (p. 704) pointed out that the type localities of *Alsophis antillensis*, having been designated St. Thomas, Guadeloupe, Martinique and Cuba, obviously constituted a composite species. Schmidt (p. 140) agreed, but added that "the name has come to be restricted to the Virgin Islands form by the consensus of opinion among herpetologists." The specimen that Schmidt summarizes is not from the Virgin Islands despite his restrictions, but was taken on Culebra. He even records the species from Puerto Rico (pp. 139, 141). He states (p. 139) that Günther (1859; p. 210) restricted the species to St. Thomas, but Brongersma (p. 3) denies this.

Schmidt requested Brongersma, who had access to the type material, to make an examination and publish his findings, which he did. The results of Brongersma's paper may be thus summarized.

SUMMARY OF BRONGERSMA'S PAPER

1. *Psammophis antillensis* Schlegel, is a composite species which the describer thought had wide distribution.

2. A lectotype must be selected to restrict the name *antillensis* to one of the components.

3. The lectotype must be selected from among the specimens upon which the description was actually based and not on others which Schlegel merely examined.

4. Schlegel mentions three cotypes of which the measurements are the only clues to their identity. These specimens are in the Leiden Museum:

a) No. 767 Leiden, labeled *Psammophis antillensis*, from Martinique, is in reality *Eudryas boddaertii* (Sentzen), from Venezuela.

b) No. 768 Leiden, labeled *Psammophis antillensis*, from Guadeloupe, chosen by Brongersma as the lectotype, is identical with *Alsophis leucomales leucomales* (Dum., Bibr. & Dum.), from Guadeloupe.

c) No. 769 Leiden, labeled *Psammophis antillensis*, from St. Thomas, collected by Richard, is in reality *Alsophis sancticrucis* (Cope), from St. Croix.

5. Schlegel did not use St. Thomas specimens in describing *Psammophis antillensis*.

6. As a result of Brongersma's action the Guadeloupe form becomes *Alsophis antillensis* (Schlegel) and *leucomales* becomes a synonym.

7. The St. Thomas form is unnamed unless, as Schmidt says, (pp. 139, 141) it is identical with *Alsophis anegadae* Barbour, in which case it takes that name.

DISCUSSION

I will endeavor to show that:

1. Leiden No. 769, labeled St. Thomas, collected by Richard, is not *A. sancticrucis*. That neither Brongersma nor Schmidt proved that it came from elsewhere than St. Thomas as labeled.

2. Schmidt did not prove *A. anegadae* identical to the St. Thomas area populations and I endeavor to show that it is different.

3. *A. nicholsi* Grant from Buck (or Capella) Islands is subspecifically different from the St. Thomas area populations and becomes *A. nicholsi nicholsi* Grant.

4. St. Thomas etc. have a population differing subspecifically from *A. nicholsi* and is therefore given a new subspecific designation.

Brongersma (p. 3) eliminated Leiden No. 769, labeled *Psammophis antillensis*, from St. Thomas, as a possible lectotype on the following grounds; "The coloration of the anterior part of the body is not that which Stejneger (p. 705, fig. 174) and Schmidt (p. 142, fig. 47) describe as typical for *Alsophis antillensis* from St. Thomas." Note that Brongersma infers that the descriptions and figure referred to are of a St. Thomas specimen. Reference to Stejneger shows that his fig. 174 is of USNM No. 25557 which was taken on Culebra Island and not on St. Thomas. Stejneger's description (pp. 704–705) is of USNM No. 25554 also from Culebra. Schmidt's fig. 41 is a copy of Stejneger's fig. 174. Schmidt (p. 141) says: "Much the best description extant is that of Stejneger, based on a Culebra specimen. . . ." Apparently the only color pattern of which Brongersma was aware was that of Culebra specimens.

Probably Brongersma would have avoided a change from a long established name by selecting Richard's St. Thomas specimen for the lectotype had he known all the facts. As it was he sent a "rough sketch" (p. 3) (see cut) of Richard's St. Thomas cotype, 769 Leiden, to Schmidt who identified the sketch as *Alsophis sancticrucis* (Cope) although Schmidt had neither St. Thomas nor St. Croix specimens for comparison. However, the sketch showed what appeared to be crossbands and Brongersma (p. 3) says the specimen has more or less distinct crossbands. On p. 4 he states that there is a specimen in the Paris Museum, No. 3574, also labeled "St. Thomas, Richard," I believe that since this specimen is unchallenged as a St. Thomas specimen, Richard's labels have not been proven untrustworthy.

I thought it necessary to locate a specimen of *sancticrucis* so that the above mentioned sketch might be compared to a real specimen. Mrs. Gaige of the MZUM, Mr. Loveridge of the MCZ, Mr. Bogert of the AMNH and Miss Margaret Storey of Stanford University all kindly answered my query to the effect that they had no specimen of *sancticrucis*. Dr. Cochran obligingly stated that the USNM had a specimen catalogued as *sancticrucis*

USNM No. 11105 from Guadeloupe, but the locality makes this specimen without interest in this case. Dr. E. R. Dunn kindly reported that the ANS had the type, No. 5404 from St. Croix. I therefore forwarded him the sketch for comparison. He stated in a letter dated Feb. 1, 1945:

"I checked the sketch of Leyden 769 directly with ANS 5404, which is one of Cope's original specimens of *sancticrucis*. The markings of the two differ considerably. The type has a light line along the meeting edges of scale rows two and three; this does not appear in the sketch. The type shows light bars running directly across the back; the sketch shows some vague and oblique light marks which do not cross the back. The ANS has two specimens from the 'West Indies' which agree closely with the type, but are more vividly marked. In my opinion the Leyden sketch does not represent a specimen of *sancticrucis*."

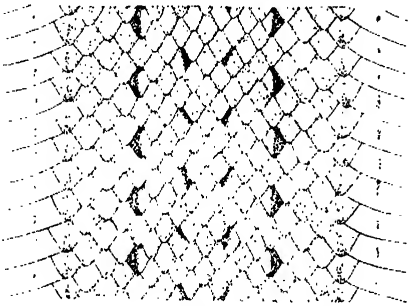

FIG. 174.—ALSOPHIS ANTILLENSIS. Color pattern around middle of body. No. 25557, U.S.N.M.

FIG. 5

The reader may compare the sketch, fig. 5 with the photo of the type, fig. 6, for himself. I invite attention to the "pattern" on the sketch. A preserved specimen of this genus is prone to lose scales by handling. When a scale rubs off it leaves a light colored area caused by exposing the lighter colored skin. The sketch shows what might well be a specimen that had received considerable handling.

I believe that the above evidence, with the illustrations, is sufficient to prove that Leyden 769 labeled St. Thomas is not *sancticrucis* and that there appears to be no reason to doubt that it came from St. Thomas.

There is little doubt but that Brongersma would have given the St. Thomas population a name had not Schmidt (p. 139) synonymized *antillensis* and *anegadae*, although he had neither St. Thomas nor Anegada material at his disposal. Schmidt stated in a letter to me dated Jan. 11, 1943: "As for the problem of *anegadae*, my reference of it to *antillensis* was based on very general resemblances." Schmidt (p. 139) includes *anegadae* in the synonymy of *antillensis*. He explains his action thus (p. 141): "The

two specimens (of *antillensis* from Puerto Rico) agree closely in coloration with the color variety described by Barbour from Anegada and, as I do not wish to admit of a discontinuous distribution of *anegadae*, it seems best to include both Puerto Rican and Anegadian specimens with *antillensis*."

FIG. 6

Brongersma stated (p. 5): "If Schmidt (pp. 139, 141) is right in referring *Alsophis anegadae* to the synonymy of the species occurring in St. Thomas, this name must replace *Alsophis antillensis* auct. (non Schlegel). As I did not examine . . . *anegadae* . . . I cannot form an opinion on the possible identity . . . and . . . must leave it to future authors. . . ."

Barbour (p. 102) in his original description of *anegadae* says: "Two

snakes from Anegada are both alike in having a squamation similar to *antillensis* but (differ from *antillensis*) in being pale ashy gray in color, the fifth scale row not parti-colored, but with a median streak of black. The upper lips are immaculate white, unspotted."

I took two specimens on Anegada, both were light tan, not gray, although I have taken gray specimens of this genus on some other islands, Peter Island for example. Both Anegada specimens had the usual parti-colored fifth row scales, differing from Barbour's description of *anegadae*. One, MZUM No. 80639A, has lips almost immaculate; No. 80639B has spotted lips. Both have numerous dark spots on all dorsal rows, a feature occasionally found on specimens from the other islets and are somewhat similar to *variegatus*. I would suggest the following diagnosis for *anegadae*: "A small, pale form differing from the populations on nearby islands in having scale pores much reduced in numbers and having dark flecks on the dorsal scales above the fifth row."

Dr. Cochran kindly sent me 9 specimens of "*A. antillensis*" labeled from St. Thomas and one specimen from Water Island. These specimens divide into three groups as far as pattern is concerned. USNM Nos. 98966, A12403 and 66523 have a dark, broken line (almost continuous on 98966) on the fifth row for the entire length of the body and in addition all rows below the patterned row are dark; rows 7–8 have spots near neck. (Note. Frequently the markings occur between rows or rather occupy the lower part of one row and the upper part of the adjacent row. I designate the rows by number to express this type of marking.) This group presents a pattern different from any I have seen. If it were possible to correlate them with an area, they would represent a well differentiated population. Nos. 66524, 12403 and 75866 have the pattern for half the length of the body and a few spots on 7 near neck; in Nos. 66525 and 66522 the pattern is reduced to about one fourth the length of body. This group agrees pretty well with the "typical *antillensis* pattern". No. 13857 is a snake of the general appearance of the *nicholsi* pattern, described below, with 4–5 marked half the length of the body and 7–8 marked on the neck. These marks are faint and the general appearance of the snake is like *nicholsi*. No. 52547 labeled from Water Island has the appearance of a reduced "*antillensis* pattern" with 5–6 spotted a fourth the length of body and 7–8 marked on neck.

Assuming that all labels are correct it would appear that the St. Thomas population had a greater diversity of patterns than that of any other island in this area and that the Buck or Capella Islands pattern was approached on St. Thomas on USNM No. 13857, reducing the *nicholsi* population to subspecific rank. No "*antillensis* pattern" has yet been taken on Buck or Capella Islands.

My original diagnosis of *nicholsi* states: "A pale form with the squamation of *antillensis* but the pattern of *portoricensis*, namely differing from typical *antillensis* in that the lateral stripe on scale rows four and five is visible only on the neck, where it is very faintly indicated, the broad dark dorsal band is likewise faint and is evidenced only by a gradual darkening of the more dorsal scales and the pattern on the eighth row is missing." Under the description of the type I said: "In life the dorsal ground color is pale olive green, which fades to pale brown in alcohol. This color is light laterally, but becomes more intense dorsally. Each scale with a diffused darker margin. On the neck there is evidence of the characteristic dark lateral band on scale rows four and five, but the characteristic marks which occur on the eighth row of *antillensis* are missing." This quotation shows that I was under the influence of fig. 174. The type locality of *Alsophis nicholsi* is Buck or Capella Islands just off St. Thomas. The specimens I took on Water Island approached *nicholsi* in general appearance.

The type of *Alsophys nicholsi* is MZUM No. 80648; paratypes 80640, 80641 and MCZ No. 46503. This form should henceforth be called *Alsophys nicholsi nicholsi* Grant. The type locality and range is Buck or Capella Islands[1] off St. Thomas, Virgin Islands.

The population occurring on St. Thomas and the Virgin Islands, excepting Anegada and St. Croix and the islands and islets east of Puerto Rico, excepting Vieques which is said to have had *portoricensis*, should henceforth be known as: *Alsophis nicholsi richardi* new subspecies.

Alsophis nicholsi richardi[2], new subspecies

Type:—USNM 66522; E. Sebastian collector; St. Thomas, V.I.; 1923, male.

Paratypes:—USNM 12403A, 12403B, A. H. Riise collector; St. Thomas, V. I.

Diagnosis:—A 19 scale row *Alsophis* bearing a broken row of particolored

[1] There are several islets called "Buck Island" among the Virgin Islands. Buck, meaning goat, is probably an influence left by the Dutch inhabitants of the Islands. It was customary to release goats on islets and capture or shoot the increase for food. Off St. Thomas lie two tiny islets nestling together like two commas with their tails separated by only about 20 feet of shallow water. Passing by these islands one would ordinarily think of them as a single island. On the charts these specks are named Capella because they are twin islets—Capella being the name of a twin star in the heavens. The fact that "Capella" means small or young goat is purely coincidental to the local name of Buck. Therefore the proper names of these rocks are Buck Island or Capella Islands.

[2] Named in honor of the original collector. It is regrettable that the two genitives should occur in the name, but I prefer to honor Richard rather than to adhere to euphony.

scales on the 5th row from the neck to a varying distance along the body; usually particolored scales above fifth row particularly at nape, occasionally extending some distance posteriorly on the eighth row. Closest to *A. anegadae*, which is a smaller, pale form with scale pores reduced in numbers and having frequently a preponderance of single pores and dark flecks on scales above the fifth row; differs from *A. nicholsi nicholsi*, which has no lateral pattern or a greatly reduced one, and from *A. portoricensis*, which bears a reticulated pattern.

SUMMARY

Brongersma studied three cotypes of *Psammophis antillensis* Schlegel, which represented three species. From these he desired to select a lectotype in order to restrict *Asaophis antillensis* (Schlegel) to a single species.

Acting on his right to select any of the three, he selected a Guadeloupe specimen to be the lectotype of *Alsophis antillensis* (Schlegel).

His action left the Virgin Islands area population, which had long been known as *A. antillensis*, without a name, unless as Schmidt claimed, *A. anegadae* Barbour and the Virgin Islands area population were identical. If this were so, the entire population would become *A. anegadae*.

The identity of the Anegada and Virgin Islands area populations has not been proven and there is good reason to believe them distinct.

Alsophis nicholsi Grant, with Buck or Capella Islands as the type locality becomes *Alsophis nicholsi nicholsi* Grant, with intergrades on Water Island.

The population on the remaining Virgin Islands, excepting Anegada and St. Croix, and on the islands and islets east of Puerto Rico, excepting Vieques, becomes *Alsophis nicholsi richardi* Grant.

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FERTILIZER REQUIREMENTS OF COFFEE GROWN ON CATALINA CLAY IN PUERTO RICO

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INTRODUCTION

Coffee is the second most important crop in Puerto Rico. About twenty per cent of the population obtain their livelihood from it. Yet, the coffee production per unit of area is very low: less than two hundred pounds of marketable coffee per acre.

Among the more obvious reasons for the low production per acre of Puerto Rican coffee, one should note that the local variety grown of *Coffea arabica* has a relatively low yield, although its berries produce a quality liquor of excellent aroma and taste, greatly preferred in the European and Cuban market. Added to the loss of this specialized market is the heavy damage inflicted by recurrent hurricanes, which has prevented the proper renovation of the coffee and shade trees and the adoption of somewhat more costly but more effective methods of cultivation. The main portion of the coffee area is on soils of the Catalina, Alonso, Los Guineos and Cialitos series, which are acid and quite low in their base exchange capacity. Because of lack of adequate fertilizer experiments on these soils, coffee growers do not know the most effective and desirable fertilizer applications to obtain maximum yields of this crop.

In his bulletin on fertilizers for coffee, McClelland (2) presented the results obtained in a series of fertilizer studies with coffee carried out at the Federal Agricultural Experiment Station at Mayaguez and elsewhere on the Island. In the summary, he made the following statements:

1. "The production over an 8-year period showed that potash was effective in increasing yield, and that this was true particularly where nitrogen was used in addition to potash." (2, p. 32.)
2. "Growth and yield failed to show that the addition of phosphoric acid was of benefit." (2, p. 32.)
3. "Until further evidence is obtained on this point, it is believed that a fertilizer for coffee should run proportionally high in potash, such, for example, as one obtained by mixing ammonium sulphate and potassium sulphate in equal parts by weight and containing approximately 10 per cent nitrogen and 24 per cent potash." (2, p. 33.)

In order to obtain more information relative to the fertilizer requirements for coffee in Puerto Rico, a fertilizer test was started by Mr. Vicente Medina on the farm of Mr. Juan Esteva, at Lares, on January 12, 1932. This experiment was carried out as originally outlined until the seventh crop was harvested in 1939, when, as a result of a study of the yield data of the first six crops, it was decided to alter the procedure in use up to that time in the check plots. Thus, the plots that had received fertilizer applications for the first seven crops, were treated similarly for the eighth and ninth crops, the last ones of this experiment; but for these last two crops, fertilizer applications were given to some of the check plots which had received no fertilizer applications for the first seven crops.

As a result of the study of the first six crops of this experiment, another fertilizer test with coffee was started at Mayaguez. Only three crops were harvested in this experiment, due to the sale of the farm on which the experiment was established, and that the new owner needed the land for other purposes.

A description of the treatments tested in these experiments and the results obtained follows in detail.

EXPERIMENT ON "CATALINA CLAY" AT LARES

Table 1 presents the treatments tested and the mean yields obtained in the plots that received the same fertilizer applications for the nine crops of the experiment established at Lares, on "Catalina Clay." In this experiment, the plots consisted of ten trees each, planted at a distance of eight feet between adjacent trees. Each plot was, therefore, 640 square feet in area, or approximately $\frac{1}{68}$ of an acre. The plots were arranged in a randomized block layout with ten replications. Five check plots, receiving no fertilizer applications, were included in each block of plots of the experiment. In table 1, however, the yields of those check plots that continued as such until the end of the test are the only ones presented.

In 1939, as has already been mentioned in the *Introduction*, a statistical study of the results obtained in the first six crops of this experiment was

made. As a result of that study, the following conclusions (1) were derived:

"The fact that no difference between the mean yields of treatments 'D', 'I' and 'J' exceeds the critical value for significance at the five per cent point, shows that potash applied in excess of 15 units did not increase significantly the yields, when the crop received in addition only five units

TABLE 1

Mean yields in hundredweights market coffee per acre of the fertilizer test performed at Lares for the nine crop cycle: 1933–1941

TREATMENTS				REPLICATIONS										
Letter	NH_3	P_2O_6	K_2O	1	2	3	4	5	6	7	8	9	10	Total
	units	*units*	*units*											
A	5	5	15	2.47	4.23	3.60	3.68	3.51	4.73	4.62	3.00	5.89	3.91	39.64
B	10	5	15	3.56	3.61	3.22	3.61	4.03	5.66	4.60	5.55	5.47	3.76	43.07
C	15	5	15	4.03	5.09	3.25	4.75	5.18	4.75	4.75	6.47	6.13	4.05	48.45
D	5	0	15	2.89	4.84	3.27	2.92	4.53	3.89	3.56	3.56	3.30	3.42	36.18
E	5	10	15	3.14	4.02	2.84	3.78	3.38	4.07	6.62	6.00	2.76	4.43	41.04
F	5	15	15	3.16	3.51	3.65	3.75	5.35	5.65	5.36	4.67	*4.82*	5.06	44.98
G	5	5	20	4.03	2.97	4.10	2.70	4.54	4.57	3.57	5.19	*4.32*	4.00	39.99
H	5	5	25	4.89	2.92	3.05	3.55	5.19	3.44	3.91	4.89	4.89	4.73	41.46
I	5	0	20	3.80	3.74	3.28	3.65	5.60	4.72	2.82	5.18	4.10	4.07	40.96
J	5	0	25	4.65	2.59	2.76	2.81	5.48	3.80	4.68	3.12	4.19	5.47	39.55
K	0	0	0	3.41	2.54	2.42	2.38	3.80	2.90	3.31	4.22	2.23	*3.17*	30.38
Total				40.03	40.06	35.44	37.58	50.59	48.18	47.80	51.85	48.10	46.07	445.70

Mean

(8) 3.964	(7) 3.999
(3) 4.307	(4) 4.146
(1) 4.845	(6) 4.096
(10) 3.618	(9) 3.955
(5) 4.104	(11) 3.038
(12) 4.498	
	44.570

Notes: 1 unit = 7.5 pounds of substance per acre. Values in italics are estimated.

of nitrogen. A similar conclusion is derived on comparing the mean yields of treatments 'A', 'G' and 'H', when the crop received five units each of nitrogen and phosphoric acid. Therefore, on this basis, it can be concluded that applications of potash at rates higher than the minimum 15 units used in this experiment were not effective in increasing the yields over the yield produced by the minimum 15 units of potash used.

"Neither five nor 10 units of phosphoric acid were sufficient to increase significantly the yields, when the crop received in addition five units of nitrogen and 15 units of potash. This conclusion is based on a comparison of the mean yields of treatments 'D', 'A', and 'E'. The application of 15 units of phosphoric acid in treatment 'F', however, produced a significant increase in yield when compared with the no-phosphoric acid application of treatment 'D'.

"Neither 10 nor 15 units of nitrogen produced any significant increases in yield over that produced by five units of nitrogen, when the crop received in addition five units of phosphoric acid and 15 units of potash. This is deduced from a comparison of the mean yields of treatment 'A', 'B', and 'C'.

"The tendency of the yields, however, is to increase with increasing amounts of both nitrogen and phosphoric acid. This is in full accord with the idea that the yield of a crop depends on the concentration of nutrients in the soil, and that the more nutrients, the higher the yield up to an optimum point. A small application of some nutrient may not prove its effectiveness in increasing the yield due to the heterogeneity of the soil, while a larger amount of the same nutrient may prove effective in so doing. This behaviour cannot be interpreted as indicating that the small application has no effect while the large application has a real effect. On the contrary, both applications are effective, only that the small one is not sufficiently effective to influence the yield statistically under the conditions in which the experiment is performed. This has happened in this case with the applications of phosphoric acid where the application of both five and 10 units did not produce a statistical increase in yield, while the 15-unit application did produce it.

"The applications of nitrogen were, according to the statistical analysis, not significant, but when used in conjunction with the application of five units of phosphoric acid—which had not demonstrated any significant effect by themselves—produced significant increases in yield.

"The applications of potash, beyond the minimum 15 units used, however, have produced no significant increases. This is not to be interpreted in the sense that potash is not necessary for high coffee yields, but in the sense that the nutrient requirements of the crop had been fulfilled with an amount of potash which was no larger, and may have been smaller, than the soil content plus the 15 units applied as minimum.

"If when the project is closed, the results are the same as those obtained to date, the recommendation would have to be in favor of the use of a fertilizer analysis containing the maximum amounts of nitrogen and phosphoric acid and the minimum amount of potash used in this test, that is, an application of about 112.5 pounds per acre each of ammonia, phosphoric

acid and potash. At that time there would be no evidence on which to recommend the use of a smaller amount of potash, since this range of potash application has not been investigated."

It must be pointed out that the use of the small amounts of phosphoric acid and the large amounts of potash tested in this experiment were due to the results obtained by McClelland (2) mentioned above. The results at the date of this study indicated, however, trends altogether different from those obtained by McClelland (2), and, accordingly, from the results expected at the time that the experiment was started.

The statistical analysis of the yield data obtained in the whole nine-crop cycle appears in table 2, and the results of the evaluation of the statistical significance of the yield differences that may be attributed to differences in the rates of application of the fertilizer substances are presented

TABLE 2

Analysis of the total sum of squared deviations of the data of table 1

SOURCE OF THE DEVIATIONS	DEGREES OF FREEDOM	SUM OF SQUARES	VARIANCE ESTIMATE	F
Blocks	9	27.3257		
Treatments	10	21.4278	2.1428	3.30**
Error	87	56.5363	0.6498	
Total	106	105.2898		

There are highly significant differences between the treatment means.
Values to be exceeded for significance between two 10-plot means:
At the 5% point........... 0.717 hundredweights market coffee per acre
At the 1% point........... 0.950 hundredweights market coffee per acre

in table 3. This table indicates that the conclusions to be derived from the results of the whole nine-crop cycle are about the same as were derived from the interpretation of the results of the first six crops of the experiment. The effect of the application of the 15 units of the nitrogen has now proved to be significant: a conclusion that was suggested but not verified by the previous study.

The lack of response to applications of potash in excess of the minimum application of 15 units, or 112.5 pounds of potash per acre, suggested the possibility of maintaining the crop yields with smaller applications of potash. To test this possibility, forty of the fifty plots which had received no fertilizer applications for the first six crops were selected for the determination of the effects on the crop yields of applications of potash below the minimum used up to that time. The treatments used in these

plots, and the results obtained in the two crops in which said treatments were tried, are presented in table 4.

Table 5 shows the results of the statistical analysis of the yield data of table 4. In table 5 it may be seen that the differences between the mean yields of the different treatments are not significant.

It should be noted that this lack of response to the potash applications was observed in plots which had received no potash applications for the previous seven crops. The conclusion that the potash applications did not increase the crop yields at the experimental site, under the conditions

TABLE 3

Significance of differences between the mean yields obtained with different amounts of application of each fertilizer substance

FERTILIZER SUBSTANCE	TREATMENT COMPARISON	DIFFERENCE BETWEEN MEAN YIELDS	REMARK AS TO SIGNIFICANCE OF DIFFERENCE
Nitrogen	B–A	0.343	Not significant
	C–B	0.538	" "
	C–A	0.881	Significant at 5% point
Phosphoric acid	A–D	0.346	Not significant
	E–A	0.140	" "
	F–E	0.394	" "
	E–D	0.486	" "
	F–A	0.534	" "
	F–D	0.880	Significant at 5% point
Potash	I–D	0.478	Not significant
	J–I	−0.141	" "
	J–D	0.337	" "
Potash	G–A	0.035	Not significant
	H–G	0.147	" "
	H–A	0.182	" "

and for the duration of the experiment, appears to be warranted by the above results. This conclusion is also in contrast with what was to be expected from McClelland's results (2).

EXPERIMENT WITH "CATALINA CLAY" AT MAYAGUEZ

The experiment at Lares started with 16-year-old trees. On that account, data on the fertilizer requirements of young coffee trees were still lacking. To obtain desired information, the other experiment mentioned in the *Introduction* was started at Mayaguez.

The latter experiment was established on a private farm at Km. 6.1 of

road No. 13 from Mayaguez to Las Marías, with six-year-old trees of the Puerto Rican variety of *Coffea arabica*. The soil of the experimental field was also a "Catalina Clay" and the trees were planted, as in the former experiment, at a distance of eight feet between adjacent trees. "Guaba" *Inga Inga* (L) Britton, and "guama" *Inga laurina* (SW) Wild, were used to provide the shade. The plots of this experiment consisted of 16 trees each, so that each plot was 1024 square feet, or approximately 1/42.54 of an acre, in area. Each treatment was replicated seven times. The

TABLE 4

Mean yields in hundredweights market coffee per acre of the fertilizer test performed at Lares for the two crop cycle: 1940–41

TREATMENTS				REPLICATIONS										
Letter	NH_3	P_2O_5	K_2O	1	2	3	4	5	6	7	8	9	10	Total
	units	*units*	*units*											
L	15	15	0	3.43	3.06	1.69	2.87	3.30	3.32	3.65	4.27	6.10	3.73	35.42
M	15	15	5	3.06	3.57	3.19	2.95	4.72	3.37	5.00	3.91	4.50	4.22	38.49
N	15	15	10	2.54	3.56	3.32	3.39	5.65	3.89	3.38	4.55	8.00	4.13	42.41
O	15	15	15	3.92	3.16	2.91	3.25	3.68	3.17	4.72	3.30	3.08	4.84	36.03

Note: 1 unit = 7.5 pounds of substance per acre.

TABLE 5

Analysis of the total sum of squared deviations of the data of table 4

SOURCE OF THE DEVIATIONS	DEGREES OF FREEDOM	SUM OF SQUARES	VARIANCE ESTIMATE	F
Blocks	9	21.8684		
Treatments	3	3.0195	1.0065	1.32
Error	27	20.5625	0.7616	
Total	39	45.4504		

The differences between the treatment means are not significant.

eleven treatments tested and the results obtained in three crops harvested in this experiment are presented in table 6. The fertilizers were applied in a narrow band six inches deep, just beneath the drip of the trees and around them. In cases where the land was too steep, the band was made in a half-moon shape on the upper side of each tree. Only one fertilizer application was made for each crop, during January, after the yearly harvest.

Table 7 shows the result of the statistical analysis of the yield data of

table 6. It shows that there were significant differences between the mean yields of the treatments.

Table 8 presents the results obtained in the evaluation of the statistical significance of the yield differences that may be attributed to differences in the rates of application of the different fertilizer substances. In it, one

TABLE 6

Mean yields in hundredweights of market coffee per acre of the fertilizer test performed at Mayagüez for the three crop cycle: 1942–44

TREATMENTS				REPLICATIONS								MEAN
Letter	NH_3	P_2O_5	K_2O	1	2	3	4	5	6	7	Total	
	pounds per acre											
A	100	0	0	2.38	2.42	2.67	1.59	1.41	1.03	1.39	12.89	1.841
B	100	100	0	1.75	2.20	3.42	1.91	1.69	2.97	2.92	16.86	2.409
C	100	0	100	2.49	2.98	1.72	0.61	1.88	2.15	2.79	14.62	2.089
D	0	100	100	3.22	2.65	3.59	2.82	1.68	1.56	1.23	16.75	2.393
E	0	0	100	3.09	1.96	1.34	2.56	1.17	2.60	1.98	14.70	2.100
F	0	100	0	5.13	1.79	2.36	2.50	1.65	2.40	2.55	18.38	2.626
G	100	100	100	2.57	2.90	3.11	2.47	1.08	2.49	1.94	16.56	2.366
H	200	100	100	2.57	2.39	2.98	1.72	0.95	1.89	2.84	15.34	2.191
I	100	200	100	5.78	2.52	3.22	3.07	2.38	4.96	1.31	23.24	3.320
J	100	100	200	2.98	3.64	1.09	3.15	2.32	4.46	3.11	20.75	2.964
W	0	0	0	1.71	2.88	1.89	0.47	1.08	1.72	1.42	11.17	1.596

TABLE 7

Analysis of the total sum of squared deviations of the data of table 6

SOURCE OF THE DEVIATIONS	DEGREES OF FREEDOM	SUM OF SQUARES	VARIANCE ESTIMATE	F
Treatments	10	16.6823	1.6682	1.99*
Error	66	55.1900	0.8362	
Total	76	71.8723		

There are significant differences between the treatment means.

Values to be exceeded for significance between two 7-plot totals:

At the 5% point........... 0.976 hundredweights market coffee per acre

At the 1% point........... 1.297 hundredweights market coffee per acre

may see that the only fertilizer substance that has affected the yields in a significant way has been phosphoric acid. This caused significant increases when applied at the rate of 100 pounds P_2O_5 per acre, in the absence of applications of nitrogen and potash, and also when applied at the rate of 200 pounds P_2O_5 per acre, in the presence of applications of 100 pounds

each per acre NH_3 and K_2O. In all the other cases, increases in the amounts of phosphoric acid applied were associated with increases in the crop yields, though in only one of the other four cases did this increase approach significance. In none of the cases were the yields affected significantly by increases in the amounts of nitrogen and potash applied. For increases in crop yield in this field during the period covered by this test, therefore, the phosphoric acid applications proved to be necessary,

TABLE 8

Significance of differences between the total yields obtained with different amounts of application of each fertilizer substance

FERTILIZER SUBSTANCE	TREATMENT COMPARISON	DIFFERENCE BETWEEN YIELDS	REMARK AS TO SIGNIFICANCE OF DIFFERENCE
Nitrogen	A–W	0.245	Not significant
	B–F	−0.217	" "
	C–E	−0.011	" "
	G–D	−0.027	" "
	H–G	−0.175	" "
	H–D	−0.202	" "
Phosphoric acid	F–W	1.030	Significant at 5% point
	B–A	0.568	Not significant
	D–E	0.293	" "
	G–C	0.277	" "
	I–G	0.954	" "
	I–C	1.231	Significant at 5% point
Potash	E–W	0.504	Not significant
	C–A	0.248	" "
	D–F	0.233	" "
	G–B	−0.043	" "
	J–G	0.598	" "
	J–B	0.555	" "

whereas the nitrogen and potash did not exert significant effects on the crop yields.

CONCLUSIONS

Two fertilizer experiments at Lares and Mayaguez were conducted on "Catalina Clay" with the Puerto Rican variety of *Coffee arabica*.

The experiment at Lares indicated that, for maximum coffee yields, nitrogen and phosphoric acid applications were required. The experiment at Mayaguez indicated that, for maximum coffee yields, phosphoric acid applications were necessary. The experiment at Mayaguez lasted

for only three crops, however, and it should be pointed out that though the beneficial effect of the nitrogen applications on the crop yields at Lares were not statistically significant with the results of the first six crops, they were with the results of the whole nine-crop cycle. Had the experiment at Mayaguez lasted long enough, the nitrogen applications might have proved to be essential for maximum crop yields. It should be remarked that the shade trees are leguminous and, therefore, they may contribute to supply at least a portion of the crop's nitrogen requirements.

Since, however, these experiments represent but two localities, further work should be done to determine the fertilizer requirements in other sections, at other altitudes, and in some of the other important soil types as regards coffee production.

SUMMARY

The results obtained in two coffee fertilizer tests performed with the Puerto Rican variety of *Coffea arabica* on "Catalina Clay" are presented, statistically analyzed, and discussed.

Nitrogen and phosphoric acid applications seem to be of greater importance as regards market-coffee production of the above variety in the soil type used, than are the applications of potash, which had no significant effects on the yields.

These results are in sharp contrast with the results obtained by McClelland, who found potash applications to be essential and phosphoric acid applications to be not essential for maximum coffee production in Puerto Rico. It should be noted that McClelland's experiments were carried out on other soil types, which were probably not in condition to provide the coffee trees with their potash requirements.

RESUMEN

Los resultados obtenidos en dos experimentos de abono realizados con la variedad Puerto Rico de *Coffea arabica* en el suelo Catalina arcilloso han sido presentados, analizados estadísticamente y discutidos.

Las aplicaciones de nitrógeno y ácido fosfórico parecen ser más importantes en cuanto se refiere a la producción de café comercial de la variedad Puerto Rico en el suelo Catalina arcilloso que las aplicaciones de potasa, las cuales no demostraron tener efectos significativos en dichos rendimientos.

Estos resultados difieren radicalmente de los resultados obtenidos por McClelland, quien encontró que las aplicaciones de potasa eran esenciales, y que las de ácido fosfórico no eran necesarias para la producción máxima de café en Puerto Rico. Debe llamarse la atención al hecho de que McClelland realizó sus experimentos en otros suelos, los cuales probablemente no

se hallaban en condiciones de proveer al cafeto la potasa requerida por el mismo.

ACKNOWLEDGMENTS

The experiment at Lares was initiated by Mr. V. Medina, Coffee Specialist, during the year 1932. Mr. J. Guiscafré Arrillaga and L. A. Gómez conducted this experiment during subsequent years. The experiment at Mayaguez was designed and initiated by Mr. J. Guiscafré Arrillaga and continued in later years by Messrs. L. A. Gómez, E. Hernández Medina and J. Lería Esmoris. Dr. B. G. Capó cooperated in the interpretation of the results at various stages of the work, and in the preparation of this manuscript.

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TRACING THE MINERAL FROM THE SOIL TO THE PLANT TO THE ANIMAL BLOOD

Part I. Effect of Lime on the Mineral Composition of the Soil, of the Grass, and on the Crop Yield

J. A. BONNET and ALFONSO R. RIERA

The land in pasture, fallow, and idle in Puerto Rico, is estimated by the 1940 Census of Agriculture to be around 776,103 "cuerdas," of which the amount of acid land dispersed in the humid area may be estimated to be about 69.3 per cent or 537,696 "cuerdas." (1 cuerda = 0.971 acre)

How the application of lime to these soils would influence the mineral composition of the soil and of the grass is not known. According to Beeson (1), fundamental studies are lacking of what changes take place in the soil when the fertilizers are supplied, and on what effect these changes will have on the plant.

This paper reports the effect that a calcium application to an acid soil has on the composition of calcium, phosphorus, magnesium, manganese, and iron of the soil, of the grass grown in this soil, and on the yield of this crop.

EXPERIMENTAL WORK

Eighteen plots, each with an area of four-tenths of an acre, were selected in a field of "Fajardo clay" at the Experiment Station Farm at Río Piedras. "Fajardo clay" is an acid red soil of the humid region, derived from old, high alluvial material and from outwash fans of adjacent shale hills. The relief is level or gently sloping.

Limestone was added on June 25, 1943 to half of the randomized plots at the rate found by the lime-requirement test reported by Riera (4). The amount of limestone applied varied from 8 to 10 tons per acre. The field was planted in the middle of July 1943 with a mixture of Para grass *Panicum purpurascens*, and Carib grass *Eriochloa polystachya*, the former known as "Malojillo" and the latter as "Malojilla". Para and Carib grasses comprise the most valuable pasture and soilage grasses in the lowlands of the northeastern part of Puerto Rico.

Five consecutive crops were harvested on the dates reported in table 1. These dates varied for each crop because the grasses were cut daily, in strips, to supply to the stable herd. The grass from each strip was weighed in the field. The third and fifth crops were fertilized with ammonium sulphate at the rate of 500 pounds per acre. From January 29 to September 15, 1945, grass from the third to fifth crops inclusive, was supplied

daily to fifteen female goats used in a supplementary experiment to find the effect of the chemical composition of this grass on their health.

METHODS OF ANALYSES

SOILS

Three composite samples of the soil were taken from each plot; the first in June 1943 previous to the lime application; the second and the third, in September 1944 and May 1945, fifteen and twenty-three months, respectively, after the lime application. Each soil sample was analyzed for pH and for exchangeable calcium, magnesium, manganese, and for available iron and phosphorus.

Exchangeable Calcium, Magnesium, Manganese. Exchangeable calcium, magnesium, and manganese, were run by Peech's (3) method as follows: Weigh 10 grams of air-dried soil and leach into a 400 ml. beaker with about 225 ml. of normal neutral ammonium acetate solution. Dry leachate carefully in a hot plate and destroy organic matter and ammonium salts, adding 5 ml. of fuming nitric acid and 1 ml. of concentrated sulphuric acid and warming until the reaction has subsided and the brown fumes are no longer given off. Cool and rinse. Evaporate to dryness at low heat and continue heating for about 10 minutes to dehydrate the salts. Place the beaker in an electric muffle at 150°–200°C. and heat to 380°C. and hold at this temperature for 10–15 minutes. Treat residue with 3 ml. of 1:1 hydrochloric acid to dissolve the oxides of manganese and iron. Evaporate to dryness on steam bath and continue heating for fifteen minutes to dehydrate silica. Dissolve the salt residue with 10 ml. of 0.1 normal nitric acid. The solution should be colorless and clear, except for a trace of silica, which is either allowed to settle out in the beaker or centrifuge if necessary in a 15 ml. centrifuge tube. The solution from the beaker is decanted into a 15 ml. test-tube. This is solution A.

Transfer 2 ml. aliquot of solution A, equivalent to 2 grams of soil, to a 15 ml. centrifuge tube for the determination of calcium and magnesium. Add 0.2 ml. of ferric chloride solution (1 ml. = 1 milligram Fe), 3 ml. distilled water, and 2 ml. of 10 per cent sodium acetate solution. Mix and add 1 ml. of 0.1 normal sodium hydroxide, and mix again. Place the centrifuge tube in a water bath kept at 95°C. Add 1 ml. of a saturated solution of bromine, and maintain water bath temperature for at least one hour to flocculate the manganese dioxide, and to expel the excess of bromine. Add 2 ml. of 25 per cent ammonium chloride solution and digest for about 15 minutes. Add a drop of methyl red; and if the color of the indicator persists, indicating complete expulsion of bromine, remove the

tube from the water bath, cool, add 0.6 normal ammonium hydroxide from a burette until the color of the solution changes from a slightly red to a deep yellow; add 2 drops in excess. In general, it usually requires 0.5 ml. of 0.6 normal ammonium hydroxide. Make up to a volume of 13 ml. with water and add 5 drops of water in excess to allow for evaporation. Mix with a stirring rod and digest in water bath at 80°C. for 5 minutes to flocculate the precipitate. Centrifuge *while hot*, for 10 minutes. Designate as solution B.

Calcium. Pipette 10 ml. of solution B. equivalent to 1.5385 grams of soil, without disturbing the manganese-iron-aluminum precipitate, into a 15 ml. centrifuge tube. This is done best by holding the tube in front of a mirror. Add 0.5 ml. of 0.5 normal hydrochloric acid and 0.9 ml. of water and place in a water bath at 70°C. Mix by spinning the tube, add 2 ml. of 3 per cent ammonium oxalate. Mix thoroughly again and digest for 30 minutes at 70°C. Remove the tube from the bath and let stand for 30 minutes. The volume of the solution at this point is 13.4 ml. The excess of 0.4 ml. evaporates and the final volume of the solution is 13 ml. Decant the clear supernatant liquid into a dry test tube and keep the test-tube inverted at an angle of 45 degrees for a few minutes. Save the liquid for the magnesium determination, (Solution C). The precipitate of calcium oxalate remains in the test-tube. Add to the precipitate, 5 ml. of 2 normal ammonium hydroxide solutions saturated with calcium oxalate, break up the precipitate with a stirring rod, wash the rod, and centrifuge for 15 minutes at 1700 r.p.m. Decant the solution, drain the tube, and discard the clear liquid. Wash again, and centrifuge, if necessary. Dissolve the precipitate with 5 ml. of ten per cent sulfuric acid solution. Heat to 70°C. in a water bath and titrate with a standard 0.025 normal potassium permanganate solution.

The amount of calcium in soil is calculated as follows:

$$\text{p.p.m. Ca in soil} = (\text{ml. } KMnO_4 \times 0.025 \times 0.02004 \times 1{,}000{,}000) \div 1.5385$$
$$= 326 \times \text{ml. } KMnO_4$$

Magnesium. Take 10 ml. of solution C, equivalent to 1.1835 grams of soil, into a 15 ml. centrifuge tube. Place the tube in a bath at 70°C., add 0.8 ml. of 2 per cent alcoholic solution of 8-hydroxyquinoline, mix immediately by stirring, and then add 0.4 ml. of concentrated ammonium hydroxide from a buret. Stir vigorously for 1 minute, or longer if the amount of magnesium is extremely small, until full turbidity develops. Wash the stirring rod with a few drops of water and replace the centrifuge tube in a water bath at 70°C for 10 minutes to flocculate the precipitate. If a number of magnesium determinations are to be carried out simultaneously,

set the centrifuge tubes aside after precipitation, until the magnesium in the last tube has been precipitated, then replace the tubes in a bath at 70°C. for 10 minutes. After digestion for 10 minutes, cool by immersing the centrifuge tubes in a bath at about 25°C., and allow to stand for 45 minutes to assure complete precipitation of magnesium; then add 0.5 ml. of 95 per cent ethyl alcohol slowly down the sides of the centrifuge tube, rotating the tube at the same time in order to wash down the precipitate and to form a layer of alcohol on the surface of the solution. Centrifuge for 15 minutes at 1700 r.p.m. and by using gentle suction draw off 2 to 3 ml. of the clear liquid to remove the layer of alcohol. Decant carefully and discard the solution; wipe the mouth of the tube with filter paper, add 5 ml. of ammoniacal ammonium acetate (8 ml. concentrated ammonium hydroxide in 300 ml. of 0.7 normal ammonium acetate), wash solution down the sides of the tube, break up the precipitate with a stirring rod, and wash the rod into the tube; add 0.5 ml. of alcohol down the sides of the tube to prevent creeping of the precipitate, and centrifuge for 15 minutes at 1700 r.p.m. Draw off the layer of alcohol, decant, and repeat the washing once more as directed above. Dissolve the precipitate in 4 ml. of 0.5 N hydrochloric acid, dilute to 13 ml. with water, stopper, and mix. Transfer a 1 ml. aliquot, equivalent to 0.0910 gram of soil to a 50-ml. volumetric flask, and add about 35 ml. of water, 5 ml. of 20 per cent sodium carbonate, and 3 ml. of phenol reagent, mixing the contents after each addition. Place the flask in boiling water for 1 minute, remove from the bath, and cool after 15 minutes. Make to volume, mix, and read in the spectrophotometer. The phenol reagent was prepared as follows: To 750 ml. of water in a 2-liter flask add 100 grams of sodium tungstate ($Na_2WO_4 \cdot 2H_2O$), 20 grams of phosphomolybdic acid ($20MoO_3 \cdot 2H_3PO_4 \cdot 48H_2O$), and 50 ml. of 85 per cent phosphoric acid. Boil for 2 hours, cool, and dilute to 1 liter with distilled water.

The transmittance-concentration curve (figure 1) for magnesium was developed as follows: Dissolve 0.15 gram of magnesium sulphate ($MgSO_4 \cdot 7H_2O$) in 100 ml. of 10 per cent ammonium chloride solution, heat to 60–70°C., add 10 ml. of the 8-hydroxyquinoline reagent, and make the solution alkaline with 4 ml. of concentrated ammonium hydroxide. Digest for 10 minutes, collect the precipitate on a fritted glass crucible, wash with hot dilute ammonium hydroxide, and dry at 140°C. Dissolve 0.0643 gram of the dried precipitate in 20 ml. of 0.5 normal hydrochloric acid and dilute to 500 ml. One milliliter contains 0.01 milligram of magnesium. Take 50 ml. of this standard solution and dilute to 100 ml. One milliliter of this second standard contains 0.005 milligrams of magnesium. The following transmittances were obtained, in a Coleman spectropho-

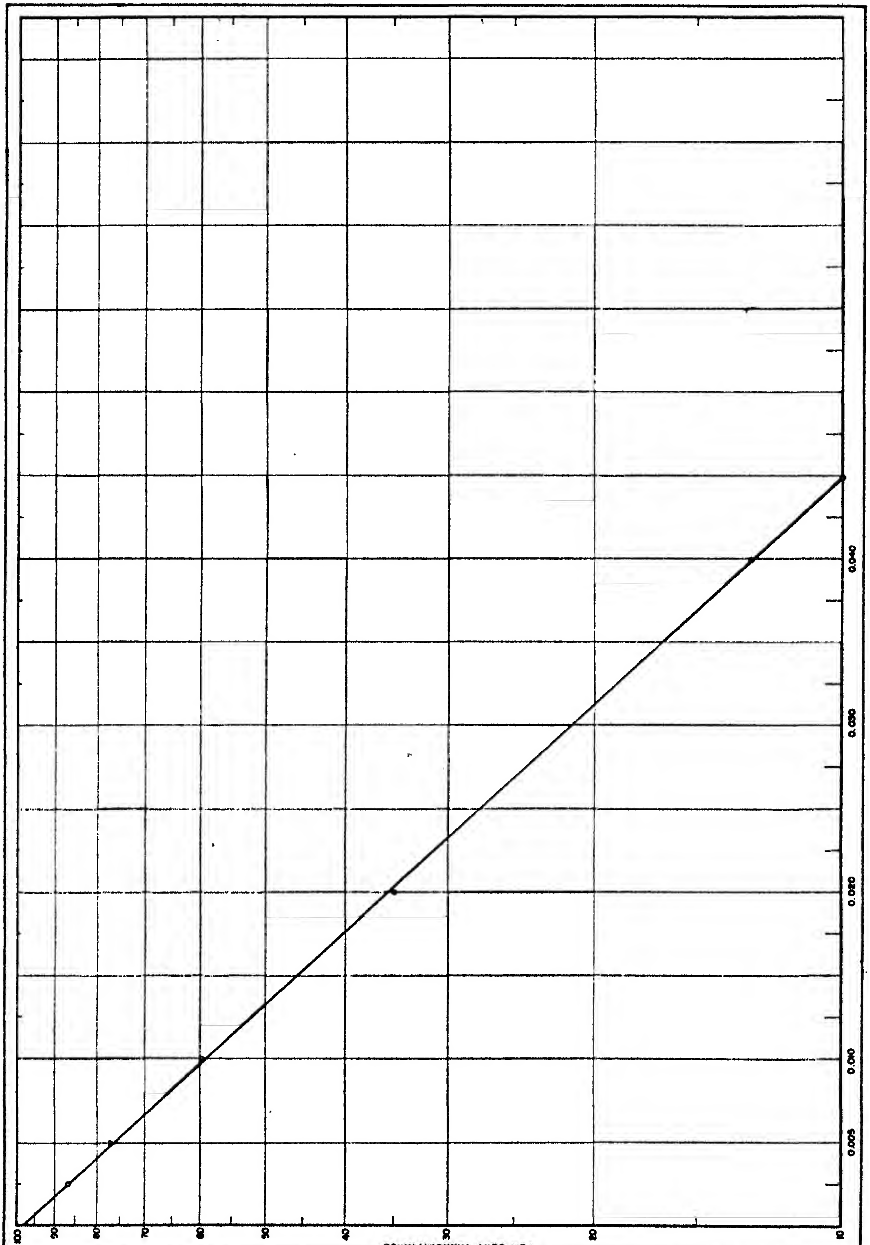

FIG. 1 Available magnesium in Soils and total magnesium in plants. Abscissa represents milligrams of magnesium as Mg.

tometer, model 11, using a PC-4 filter and a wave length of 650 mμ (figure 2), and a reagent blank as reference solution:

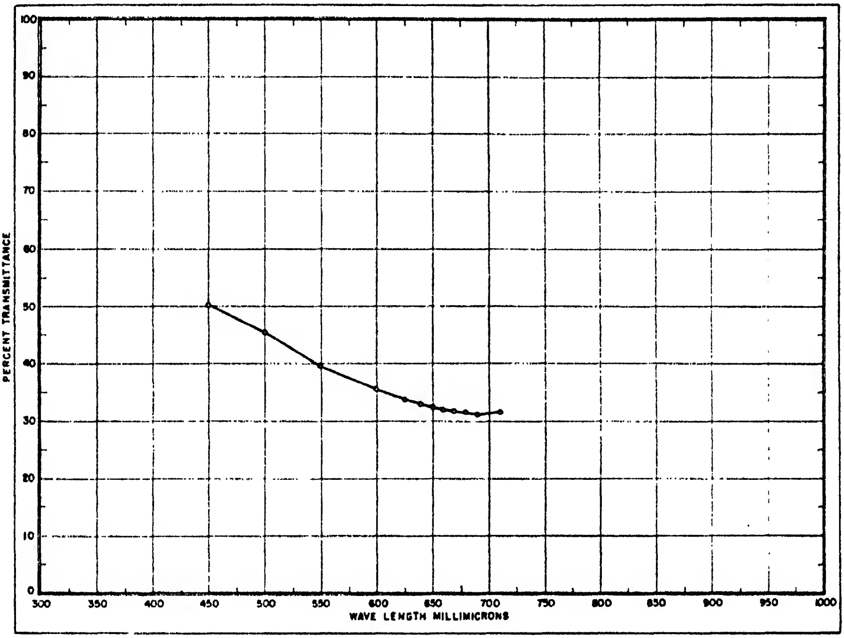

FIG. 2 Spectral-Transmittance curve for magnesium, as per method for soils and plants.

STANDARD MAGNESIUM SOLUTION		TRANSMITTANCE
ml.	*mg. Mg*	%
0.5	0.0025	87.0
1	0.005	77.2
2	0.010	59.8
4	0.020	35.1
8	0.040	12.9
10	0.050	8.9

The color was developed as explained in the procedure.

The amount of magnesium in soil is calculated as follows:

$$\text{p.p.m. Mg in soil} = \frac{\text{milligrams Mg in curve} \times 1{,}000{,}000}{1{,}000 \times 0.0910}$$

$$= \text{mgm. Mg} \times 10{,}989$$

Manganese. Manganese was determined by the simplified periodate method described by Peech (3). Transfer 2 ml. of solution, equivalent to 2 grams of soil, to a test-tube graduated at 11 ml. Add 1 ml. of 85 per cent

phosphoric acid, dilute to 11 ml. with water, and add 0.3 ml. to allow for evaporation, and mix with a stirring rod. Place in a water bath at 95°C., add about 50 milligrams of sodium periodate, mix thoroughly agair, and leave in the bath for 1 hour to assure full color development. Cool, make to volume if necessary; mix and read in the spectrophotometer.

The transmittance-concentration curve (figure 3) for manganese was developed as follows: To 22.8 ml. of 0.1 normal potassium permanganate solution in a 250 ml. Erlenmeyer flask, add about 50 ml. of water and a few drops of concentrated sulfuric acid. Heat to boiling and reduce the permanganate by the addition of sodium sulfite until the solution is colorless. Boil off the excess of sulfur dioxide and dilute to one liter. One milliliter of this solution is equivalent to 0.025 milligrams of Mn. The following transmittances were obtained in a Coleman spectrophotometer, model 11, using a PC-4 filter and a wave length of 525 mμ (figure 4) and a reagent blank as reference solution:

STANDARD MANGANESE SOLUTION		TRANSMITTANCE
ml.	*mg. Mn*	%
1	0.025	79.8
2	0.050	63.6
3	0.075	51.0
5	0.125	33.5
8	0.200	19.1
10	0.250	13.9

The color was developed as explained in the procedure.

The amount of manganese in soil is calculated as follows:

$$\text{p.p.m. Mn in soil} = \frac{\text{milligrams Mn in curve} \times 1{,}000{,}000}{1{,}000 \times 2}$$

$$= 500 \times \text{mg. Mn in curve}$$

Available Phosphorus and Iron. Available phosphorus and iron in the soil were extracted with Morgan's Universal extracting solution, normal sodium acetate buffered at pH 4.8 with acetic acid as follows: 12.5 grams of air-dried soil and 25 ml. of extracting solution were placed in a test-tube, 6″ long and 1″ in diameter. The tube was stoppered and shaken horizontally for 2 minutes, in a reciprocating shaker (Amer. Instrument Co. cat. #7-155) at a speed of about 120 shaking cycles per minute. The extract was filtered in a Whatman filter paper No. 1.

Available Phosphorus—Phosphorus was precipitated as ammonium phosphomolybdate, reduced to the blue color with aminonaphtholsulfonic acid and determined colorimetrically as per Wolf's (5) procedure as follows: Take an aliquot of 5 ml. of soil extract, equivalent to 2.5 grams of soil,

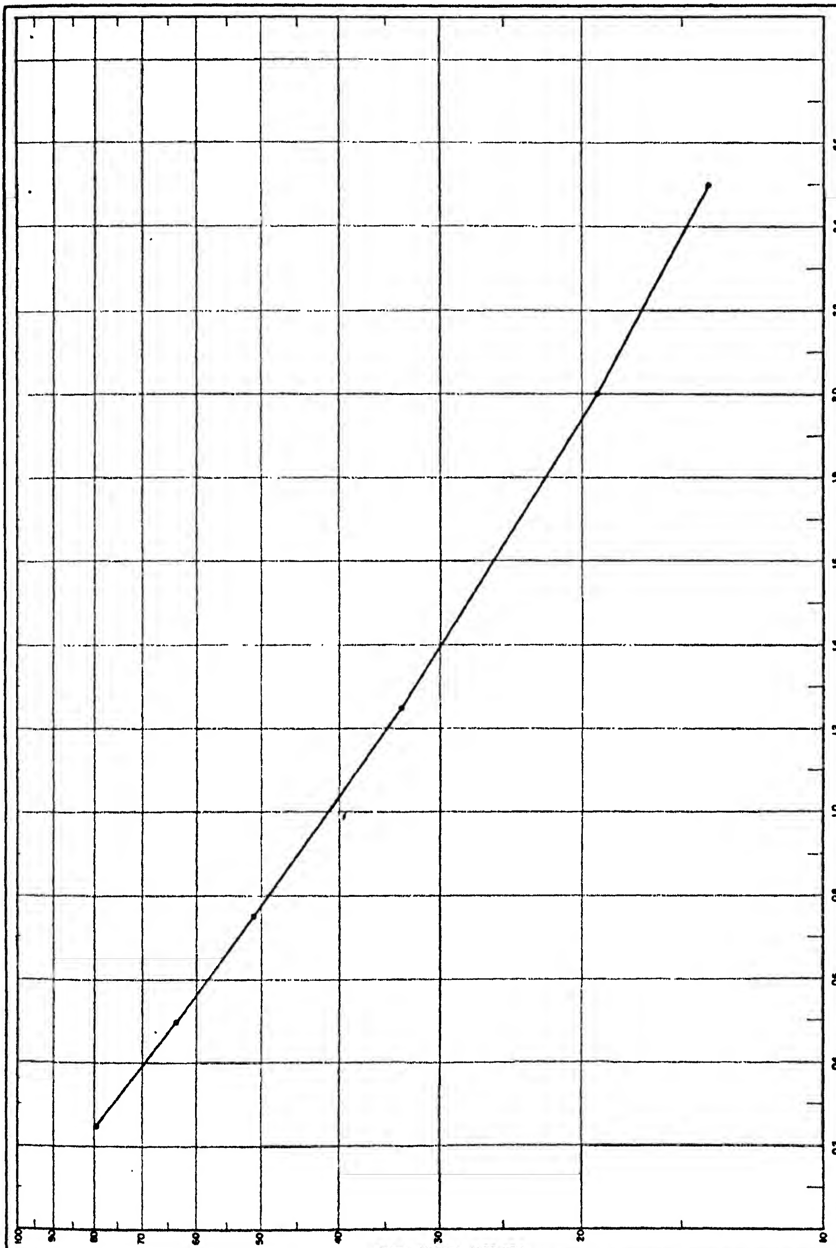

Fig. 3 Available manganese in soils and total manganese in plants. Abscissa represents milligrams of manganese as Mn.

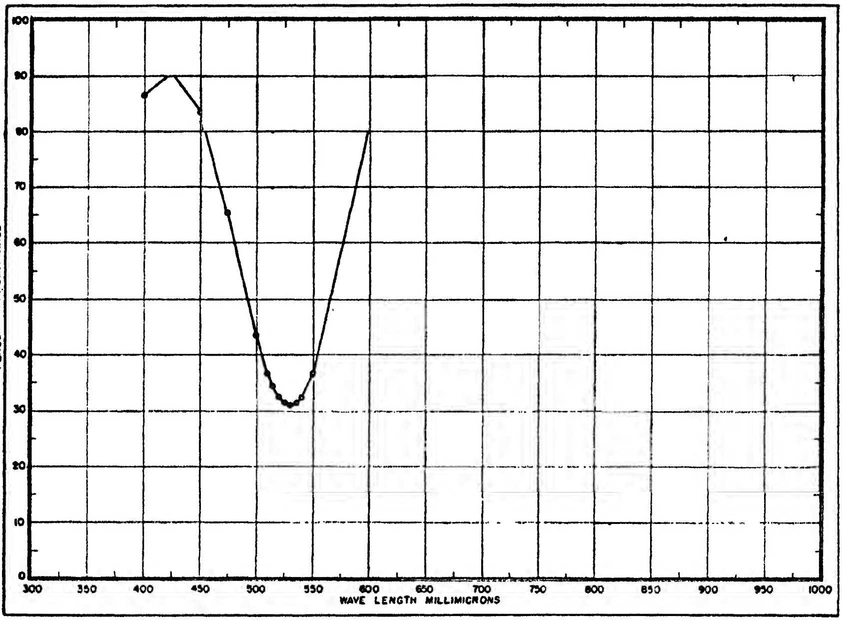

Fig. 4 Spectral-Transmittance curve for manganese as per method for soils and plants.

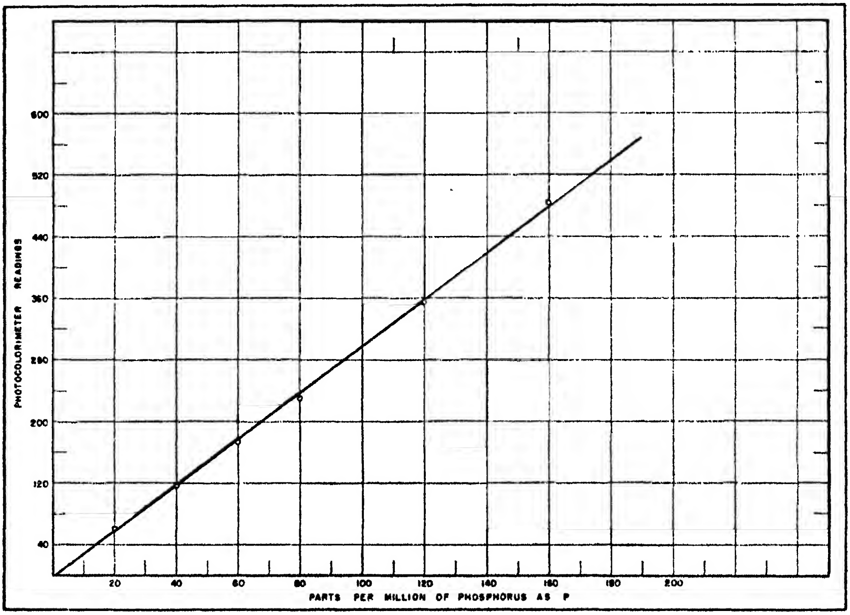

Fig. 5 Available phosphorus in soils.

dilute to 20 ml. with extracting solution, add 4 ml. of ammonium molybdate solution (2.5 per cent in 6 normal sulfuric acid, and 2 ml. of aminonaphthol-sulfonic acid solution (15 grams of anhydrous sodium bisulfite, are dissolved in 100 ml. of water, and 0.5 gram of pure, dry 1-amino-2-naphthol-4-sulfonic acid, and 1.5 grams of anhydrous sodium sulfite, are added; shake, make up to 500 ml. and store in a brown bottle).

The concentration curve for phosphorus (figure 5) was obtained in a Klett-Summerson photoelectric colorimeter No. 2141 with red filter 66 covering wave lengths from 640 to 700 mμ and instrument set at zero with reagent blank. The procedure was as follows: Weigh 0.1006 grams of sodium monobasic phosphate ($NaH_2PO_4 \cdot 2H_2O$) and dissolve in one liter of water. One milliliter of this solution is equivalent to 20 parts P per million. The following readings were obtained in the photoelectric colorimeter:

STANDARD PHOSPHORUS SOLUTION			PHOTOCOLORIMETER READING
ml.	*mg. P*	*p.p.m. P*	
1	0.02	20	60.5
2	0.04	40	115.4
3	0.06	60	174.4
4	0.08	80	229.9
6	0.12	120	353.5
8	0.16	160	483.0

The slope of this curve was found not to be constant. To check the slope, three phosphorus standards should be run with the unknown.

The amount of phosphorus in soil is calculated as follows:

$$\text{p.p.m. available P in soil} = \text{p.p.m. P in curve} \times \frac{1}{2.5}$$
$$= \text{p.p.m. P in curve} \times 0.4$$

Available Iron—An aliquot of 1 ml. of the soil extract equivalent to 0.5 gram of soil, was poured in a test-tube graduated at 10 ml. The color was developed as per method of Saywell and Cunningham, described by Parks et al (2), as follows: Add 1 ml. of 10 per cent hydroxylamine hydrochloride solution and 0.5 ml. of ortho-phenanthroline (1.5 per cent in 95 per cent ethanol), make to volume, mix and read in the photoelectric colorimeter. As the original extract was buffered to pH 4.8 there was no need of adjusting the pH with ammonium hydroxide as mentioned by Parks.

The concentration curve (figure 6) for iron was developed as follows: Weigh one-gram of c.p. iron wire in a liter volumetric flask and dissolve in about 150 ml. of 1:6 sulfuric acid; add 5 ml. of concentrated nitric acid as oxidizing agent; boil to expel SO_3 fumes, and complete volume to one liter.

One milliliter of this solution is equivalent to one milligram Fe. Ten milliliters of this solution were diluted to one liter; one milliliter of this solution contains 0.01 milligrams Fe. The following readings were obtained in a Klett-Summerson photoelectric colorimeter, No. 2141, with blue filter 42

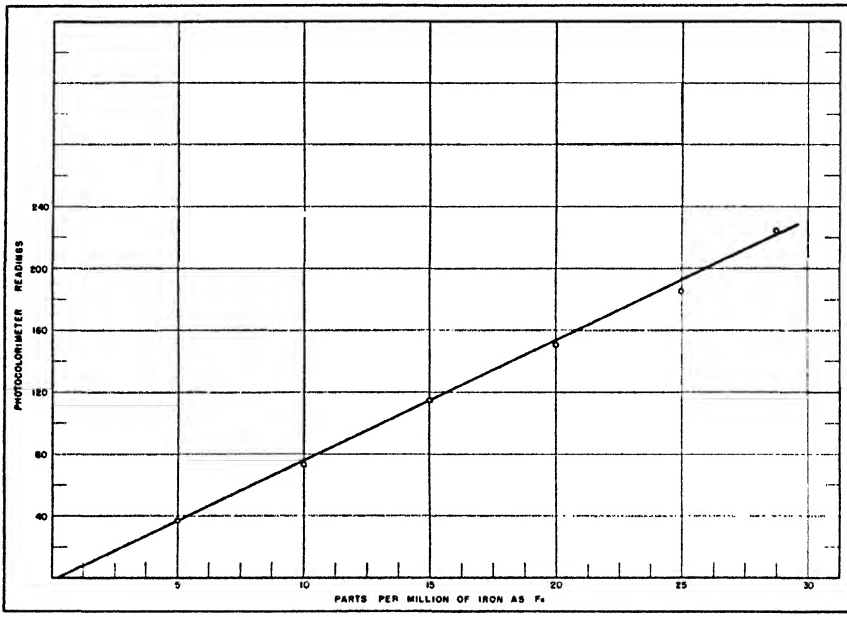

FIG. 6 Available iron in soils.

covering wave lengths from 400–465 mμ, and the colorimeter set at zero with reagent blank:

STANDARD IRON SOLUTION			PHOTOCOLORIMETER READING	SLOPE FACTOR
ml.	*mg. Fe*	*p.p.m. Fe*		
0.5	0.005	5	37	.1351
1.0	0.010	10	73	.1370
1.5	0.015	15	115	.1304
2.0	0.020	20	151	.1325
2.5	0.025	25	184	.1351
3.0	0.030	30	224	.1339

The color was developed as explained in the procedure. The slope of the curve was found to be constant; its average value is 0.1340.

p.p.m. available Fe in soil = p.p.m. Fe in curve $\times$ 2

= photocolorimeter reading $\times$ 0.1340 $\times$ 2

= 0.268 $\times$ photocolorimeter reading

GRASS

A composite sample (about ten pounds) of the standing grass was taken from each plot. The samples were dried to constant weight in a hot air oven at 150°F. Each sample was ground in a Wiley mill and sifted through a 1 mm. sieve. The ground samples were left overnight at room temperature to absorb atmospheric moisture. The dates of grass samplings are reported in table 1.

A 7.50 gram sample of dry grass was weighed in a 600 ml. pyrex beaker for each determination and the procedure of Parks et al (2), omitting the dithizone extraction, was followed as explained below.

Destruction of Organic Matter and Removal of Silica. Destroy the organic matter with nitric and perchloric acids; add first 12.5 ml. of concentrated nitric acid, place a cover glass on top of the beaker, and heat in a steam plate or hot plate at low temperature, in the hood; add again 12.5 ml. of nitric

TABLE 1

Dates of soil and grass samplings, of fertilizer application, of harvesting, and age of grass at harvest time

CROP	DATES OF SOIL SAMPLING	DATES OF GRASS SAMPLING	DATES OF AMMONIUM SULPHATE APPLICATION	HARVESTING DATES	AGE OF CROP HARVESTED	
					At start	At end
					mo.	*mo.*
First	6/43			1/13–27/44	5.5	6.0
Second	9/44	8/28/44		8/28–11/14/44	7.0	9.5
Third		11/16/44	10/10/44	11/15/44–3/29/45	2.5	4.5
Fourth	5/45	4/10/45		3/30–7/29/45	4.5	4.0
Fifth		7/16/45	4/25/45* 6/5/45*	7/30–10/25/45	4.0	3.0

* Only one application; dates refer to application for half of each plot.

acid and evaporate to near dryness. Add to residue 25 ml. of concentrated nitric acid and 25 ml. of 60 per cent perchloric acid. Do not add the perchloric acid before the nitric acid treatment because an explosion may occur. Evaporate to near dryness. Transfer residue quantitatively into a 125 ml. platinum dish, washing four or five times with 5 ml. portions of water. Add 5 to 8 ml. of 48 per cent hydrofluoric acid, from an 8 ml. beaker coated with paraffin, to the platinum dish; heat in hot plate carefully to dryness until silicon fluoride fumes are totally driven off. While working with grass samples from the dry area of Puerto Rico, a pink color persisted in this stage. It was destroyed by adding a pinch of peroxydisulfate ($K_2S_2O_8$) salt and a few drops of concentrated nitric acid. Cool, add 10 ml. of hot 0.6 normal hydrochloric acid, and dissolve the salts by continued heating and crushing of solid material with a flat end glass rod. Transfer to a 100 ml.

volumetric flask. Repeat heating-crushing operation, until the salts go in solution. Make up to 100 ml. volume with water and label, "Solution A"; 1 milliliter of this solution is equivalent to 0.075 gram of plant tissue.

Manganese. Manganese was determined by the simplified periodate method described by Peech (3). Pipette a 10 ml. aliquot of "Solution A" equivalent to 0.75 gram of plant tissue, into a 50 ml. beaker and evaporate to dryness, in a hot plate, to remove excess of hydrochloric acid. Dissolve residue in 6 ml. of normal nitric acid and transfer to a test-tube graduated at 11 ml. and follow the procedure explained before for the soils.

The transmittance-concentration curve (figure 3) was also developed as explained for the soils.

The amount of manganese in plant is calculated as follows:

$$\text{p.p.m. Mn in plant} = \frac{\text{milligrams Mn in curve} \times 1{,}000{,}000}{1000 \times 0.75}$$

$$= 1333 \times \text{mg. Mn in curve.}$$

Iron. Pipette 1 ml. of "Solution A" equivalent to 0.075 gram of plant tissue into a test-tube graduated to 10 ml. and develop color as explained before for soils.

Transmittance was measured this time in a Coleman spectrophotometer, model 11. The transmittance-concentration curve for iron (figure 7) was determined in the same standard used for soils. The following transmittances were obtained with filter PC-4, at a wave length of 490 mμ, using a reagent blank as reference solution:

STANDARD IRON SOLUTION		TRANSMITTANCES
ml.	*mg. Fe*	%
0.5	0.005	79.2
1.0	0.010	61.3
1.5	0.015	48.1
2.0	0.020	37.4
2.5	0.025	30.0
3.0	0.030	24.0

The amount of iron in plant is calculated as follows:

$$\text{p.p.m. Fe in plant} = \frac{\text{milligrams Fe in curve} \times 1{,}000{,}000}{1{,}000 \times 0.075}$$

$$= 13{,}333 \times \text{mg. Fe in curve.}$$

Phosphorus. Pipette a 0.1 ml. of solution A, equivalent to 0.0075 gram of plant tissue into a test-tube graduated at 10 ml. using a 0.1 ml.

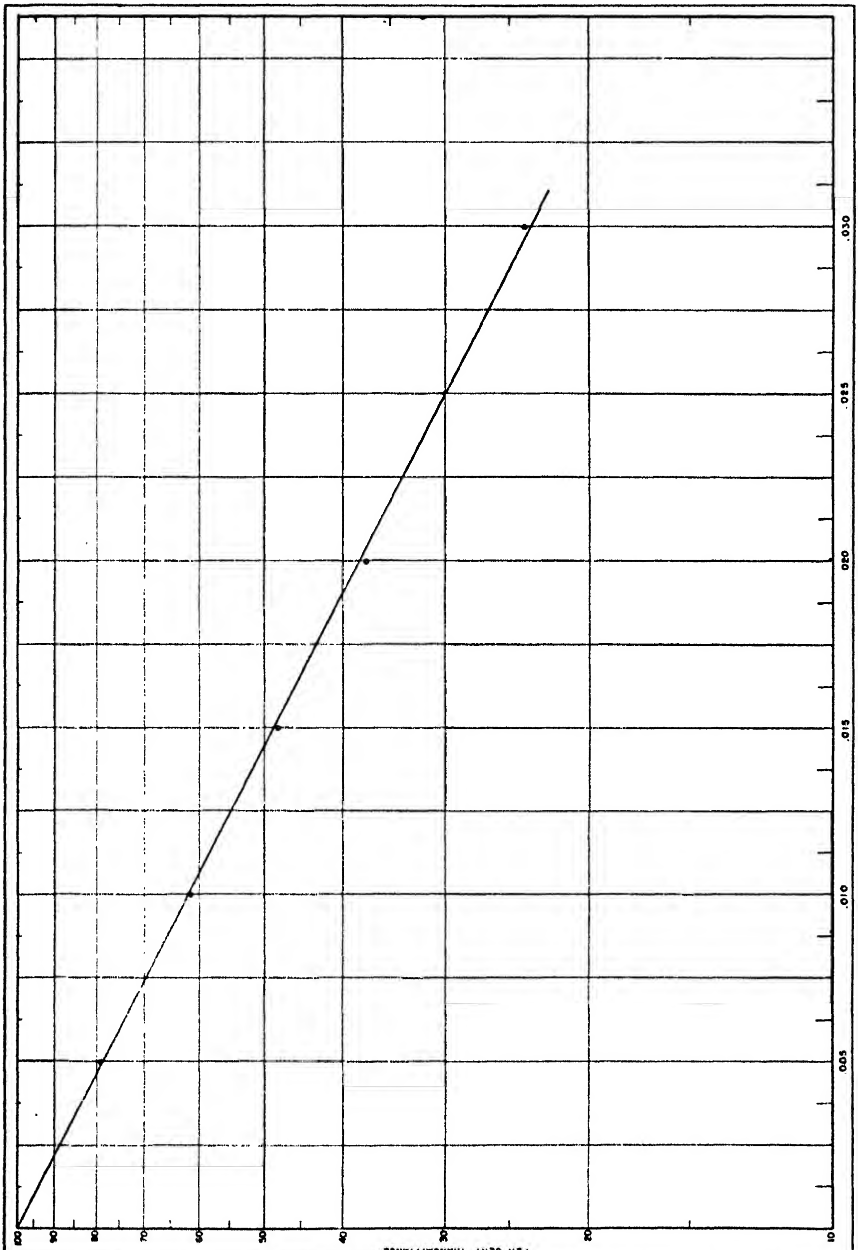

FIG. 7 Iron in plants. Abscissa represents milligrams of iron as Fe.

Mohr's pipette. Add 1 ml. of water and discharge the pipette by blowing with the tip under the water. Add 1 ml. of ammonium molybdate solution (2.5 per cent in 5 normal sulfuric acid), mix, and add 0.4 ml. of 0.25 per cent aminonaphtholsulfonic acid solution (0.125 gram of aminonaphtholsulfonic acid to 49 ml. of filtered 15 per cent sodium bisulfite, and then adding 1.25 ml. of 20 per cent sodium sulfite). Make to volume and mix. Read transmittance in spectrophotometer.

The transmittance-concentration curve for phosphorus (figure 8) was obtained in a Coleman spectrophotometer, model 11, with filter PC-4, at a wave length of 600 mμ, using distilled water as reference solution. The following transmittances were obtained in eight phosphorus standard solutions prepared as explained in the soils procedure:

STANDARD PHOSPHORUS SOLUTION		TRANSMITTANCE
ml.	*mg. P*	%
1.0	0.0050	83.1
1.5	0.0075	78.5
2.0	0.0100	72.9
3.0	0.0150	63.0
3.5	0.0175	58.6
4.0	0.0200	54.1
5.0	0.0250	46.7
5.5	0.0275	43.5

The slope of this curve was found not to be constant. It is suggested to run three standard solutions with the unknown.

The calculation of phosphorus in plant is as follows:

$$\text{p.p.m. P in Plant} = \frac{\text{milligrams P in curve} \times 1{,}000{,}000}{1{,}000 \times 0.0075}$$

$$= 133{,}333 \times \text{mg. P in curve.}$$

Removal of Iron, Aluminum, and Phosphorus Previous to Calcium and Magnesium Determinations. Transfer a 2.0 ml. aliquot of solution A, equivalent to 0.15 gram of plant tissue, to a 15 ml. centrifuge tube graduated at 13 ml. Add 0.2 ml. of ferric chloride solution (1.22 grams of ferric chloride hexahydrate in 250 ml. of 1 to 250 hydrochloric acid), mix, add 8 ml. of buffer solution (25 grams of sodium acetate, 62.5 grams of ammonium chloride, and 0.5 gram of sodium hydroxide in 1 liter of solution), and mix again. Add 1 drop of methyl red indicator solution (0.02 per cent) and 0.6 N ammonium hydroxide until the color of the solution changes from slightly red to deep yellow, and then add 2 drops in excess. Dilute to about 13.2 ml., mix with a stirring rod, and digest in a water bath at 80°C. for 5 minutes to flocculate the precipitate. Mix thoroughly, and centrifuge

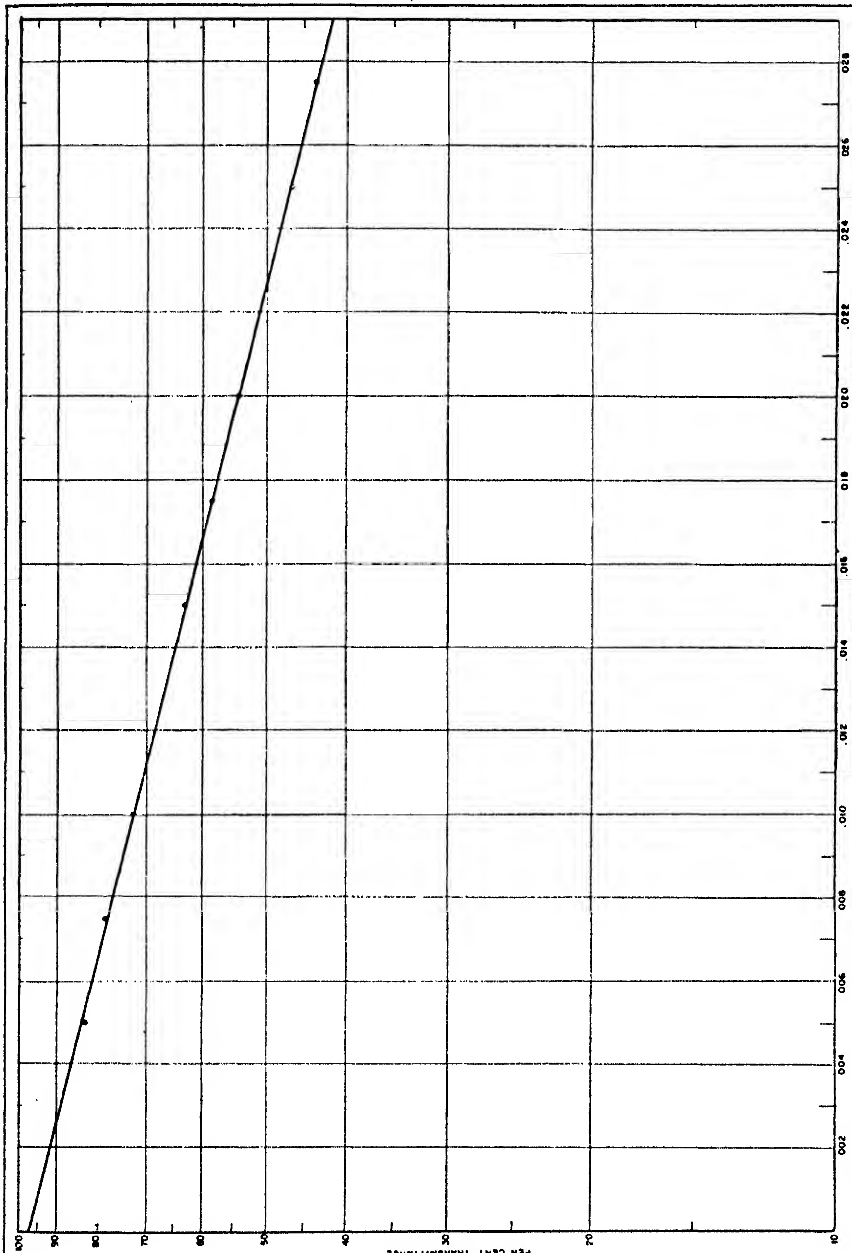

FIG. 8 Phosphorus in plants. Abscissa represents milligrams of phosphorus as P.

while hot for 10 minutes. The solution should have evaporated to 13.0 ml.

Calcium. Calcium was determined by the method of Peech (3). Transfer a 10 ml. aliquot from the above 13 ml. clear solution, equivalent to 0.1154 gram of plant tissue, into another calibrated 15 ml. centrifuge tube; add 1.4 ml. of 0.2 normal hydrochloric acid, and place in a water bath at 70°C. Mix; add 2 ml. of 3 per cent ammonium oxalate, mix thoroughly again, and digest for 30 minutes at 70°C. Remove the tube from the bath and let stand for 30 minutes. Centrifuge for 15 minutes, at about 2000 r.p.m. The volume should now be 13 ml. Decant the clear supernatant liquid gently into a 25 ml. test-tube and save for the magnesium determination.

Allow the centrifuge tube to drain for several minutes, inclined at a 45° angle, on a filter paper. Add quickly from a pipette, about 5 ml. of 2 normal ammonium hydroxide saturated with calcium oxalate, centrifuge for 15 minutes, decant carefully and discard the solution. Drain the tube and save the precipitate. One washing is sufficient unless very large quantities of calcium are present. Add about 5 ml. of 10 per cent sulfuric acid, heat to 70°C. on a water bath, and titrate with standard 0.025 normal potassium permanganate.

$$\text{p.p.m. Ca in plant} = \frac{\text{ml. } KMnO_4 \times 0.025 \times 0.02004 \times 1{,}000{,}000}{0.1154}$$

$$= 43{,}413 \times \text{ml. } KMnO_4$$

Magnesium. Magnesium was also determined by the method of Peech (3). Pipette 10 ml. of supernatant liquid, from the solution set aside for the magnesium determination, equivalent to 0.0887 gram of plant tissue, in a 15 ml. centrifuge tube graduated at 13 ml. and proceed as described in the magnesium determination reported before for soils. Take a 2 ml. aliquot from the 13 ml. solution, equivalent to 0.01365 gram of plant tissue, and develop color as mentioned previously for soils. Read transmittance in curve (figure 1).

$$\text{p.p.m. Mg in plant} = \frac{\text{milligrams Mg in Curve} \times 1{,}000{,}000}{1{,}000 \times 0.01365}$$

$$= 73{,}260 \times \text{mg. Mg in Curve}$$

Proteins, Ether Extract and Fiber. Proteins, ether extract, and fiber were determined in the first, second and third crops. Proteins were also determined in the fourth crop, previous to and after the second application of ammonium sulphate.

PRESENTATION AND DISCUSSION OF DATA OBTAINED

The mineral changes brought about in the soil, fifteen and twenty-three months after the lime application, are expressed in table 2.

The increase of available calcium and phosphorus and the decrease of available iron in the soil due to liming, was highly significant, fifteen and twenty-three months after the lime was applied to the soil. The decrease of available manganese in the soil due to liming was highly significant fifteen months after liming and significant twenty-three months after liming. The difference between the available magnesium content of the limed and unlimed soil was not significant.

TABLE 2

Parts per million of available calcium, magnesium, manganese, phosphorus, and iron in soil type Fajardo clay, unlimed and limed (dry basis)

TIME OF SAMPLING	TREATMENT	CALCIUM (Ca)	MAGNESIUM (Mg)	MANGANESE (Mn)	PHOSPHORUS (P)	IRON (Fe)
		p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
15 months after liming	Unlimed	849	180	42	13	17
	Limed	6831	172	8	61	2
23 months after liming	Unlimed	992	156	29	21	45
	Limed	5351	156	5	56	12

TABLE 3

Parts per million of calcium, magnesium, manganese, phosphorus and iron in three crops of Para-Carib grass grown in soil Type Fajardo Clay, unlimed and limed (air dry basis)

CROP NUMBER	TIME OF SAMPLING	TREATMENT	CALCIUM (Ca)	MAGNESIUM (Mg)	MANGANESE (Mn)	PHOSPHORUS (P)	IRON (Fe)
			p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
Second	14 months after liming	Unlimed	2199	1509	229	2100	149
		Limed	2811	1638	137	2430	158
Third	17 months after liming	Unlimed	2008	1824	156	2749	196
		Limed	3351	2212	84	3047	160
Fourth	32 months after liming	Unlimed	2919	2166	243	2450	124
		Limed	3381	2088	181	2929	121

The mineral changes brought about in the grass after the lime application are expressed in table 3.

The increase of calcium and the decrease of manganese in the grass due to liming was highly significant for the second and third crops while the increase of calcium was significant for the fourth crop, and the decrease of manganese was not significant. The increase of phosphorus in the grass due to liming was highly significant for the second and fourth crops but was not significant for the third crop. There was no significant change in the iron

content of the grass due to liming in the three crops and in the magnesium content of the second and fourth crops. However, the increase of magnesium in the grass crop due to liming was highly significant for the third crop.

The average total yield of green grass per acre in the unlimed and limed soil for each of the first five consecutive crops, and for the five crops, is reported in table 4.

The increase in the grass yield due to liming was significant for the first and third crops. However, the difference between the respective yields of the unlimed and limed soil for the second, fourth and fifth crops, and for the total of five crops, was not significant.

TABLE 4

Yield in tons per acre of green Para-Carib grass in Fajardo clay unlimed and limed

TREATMENT	NUMBER OF CROP					TOTAL
	1 No nitrogen applied	2 No nitrogen applied	3 Nitrogen applied	4 No nitrogen applied	5 Nitrogen applied	
Unlimed	8.98	7.47	9.59	8.92	9.82	44.78
Limed	11.00	8.03	10.33	8.62	9.81	47.79

TABLE 5

Grass yields of table 4 expressed as tons per acre per month of green grass

TREATMENT	NUMBER OF CROPS AND AGE IN MONTHS				
	1 5.75 mo.	2 8.25 mo.	3 3.50 mo.	4 4.25 mo.	5 3.50 mo.
Unlimed	1.56	.91	2.74	2.10	2.81
Limed	1.91	.97	2.95	2.03	2.80

The monthly rate of growth for each of the five grass crops is reported in table 5. The age of the crop used for this calculation was the mean of that reported in table 1.

The increase in the yield of the third grass crop is due to nitrogen fertilization. It gave about two tons of green grass more per acre than the previous crop (table 4). The monthly rate of growth was about three times higher (table 5). In a period of 7.75 months, the third and fourth crops combined gave close to 5 tons of green grass per acre, while the unfertilized second crop in 8.25 months gave about one ton. In fourteen months the first two unfertilized crops gave about three tons of green grass per acre.

However, in about a period of one year the last three crops gave about eight tons of green grass per acre. The eight-ton year yield was obtained with two applications of nitrogen fertilizer, one to the third crop and another to the fifth crop, each at the rate of 500 pounds of ammonium sulphate per acre.

The increase of grass yield is not the only advantage obtained when nitrogen is applied. The content of the nitrogen in the crop is also increased if the grass is cut early (table 6).

The protein content of the Para-Carib grass mixture ranged between 3 and 4 per cent. Grass from the third crop taken 36 days after the first nitrogen application gave around 11 per cent protein or about three times that in the original grass. The ammoniacal content in the third crop was .07 and .05 per cent, respectively, for the unlimed and limed grass. The protein content of the fifth grass crop, collected 82 days after the nitrogen application, was about 5 per cent.

TABLE 6

Protein content of Para-Carib grass in five consecutive crops, before and after nitrogen fertilization (air-dried-basis)

TREATMENT	CROP 1, NO NITROGEN APPLIED	CROP 2, NO NITROGEN APPLIED	CROP 3, 36 DAYS AFTER FIRST NITROGEN APPLICATION	CROP 4, 180 DAYS AFTER FIRST NITROGEN APPLICATION	CROP 5, 82 DAYS AFTER SECOND NITROGEN APPLICATION
	%	%	%	%	%
Unlimed	3.6	3.8	11.7	3.3	4.8
Limed	3.8	3.7	10.8	3.6	4.5

SUMMARY

This paper reports the procedures followed for the chemical determinations of exchangeable calcium, magnesium, and manganese; and available phosphorus and iron in soils; and for the total amount in plants of each of those minerals mentioned. Spectrophotometric methods are given for magnesium and manganese in soils and plants; and for phosphorus and iron in plants including the transmittance-concentration and spectral-transmittance curves for each of these elements. Photocolorimetric methods are also given for available iron and phosphorus in soils with their corresponding curves.

This paper reports also changes of the minerals calcium, magnesium, manganese, phosphorus and iron in an acid soil, 15 and 23 months after liming. It also reports changes of these minerals in each of five crops of a mixture of Para grass *Panicum purpurascens*, and Carib grass *Eriochloa polystachya*, grown in the unlimed and limed soil. The yield of green grass is also reported for each crop.

The important results are as follows:

1. Significant increases of available calcium and phosphorus and significant decreases of available manganese and iron in the soil, due to liming, and no significant [redacted]f the available magnesium content.
2. Significant increase of calciu[redacted]ant decrease of iron in each of three consecutive crops [redacted] due to liming. Significant decrease of manganese in the first two crops but no significant difference in the third crop. No significant difference in the magnesium content of the first and third crops but a significant difference in the middle crop.
3. The increase in the grass yield, due to liming, was significant for the first and third crops but was not significant for the second, fourth, and fifth crops, or for the total of the five consecutive crops.
4. An application of 500 pounds of ammonium sulphate per acre gave about two tons of green grass more per acre than a previous unfertilized crop. The period of growth of the fertilized grass was 3.5 months while that of the unfertilized grass was 8.25 months.
5. Grass collected early, 36 days after the nitrogen application, contained around 11 per cent of protein or about three times as much as in the unfertilized grass.

ACKNOWLEDGMENT

The writers wish to express their appreciation to Miss Gloria María Soto, former Junior Chemist of the Soils Department, for technical help on some analyses of the soils and grass samples.

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TRACING THE MINERAL FROM THE SOIL TO THE PLANT TO THE ANIMAL BLOOD

Part II. Effect of Unlimed and Limed Grass on the Chemical Composition of Goats' Blood

J. A. BONNET, A. R. RIERA, L. RIVERA BRENES AND R. ORLANDI

The effect of lime applications on the composition of calcium, magnesium, manganese, phosphorus and iron, in the acid red soil type "Fajardo clay", and on a mixture of "Para and Carib" grass, was discussed in Part I published by Bonnet and Riera (1).

This paper presents information on the effect of the unlimed grass, the limed grass, and the limed grass supplemented with manganese per os, on the weight of the goat; on the grass consumed; and on the hemoglobin, calcium, phosphorus, iron, hematocrits, red-blood cells, and white-blood cells of the goats' blood.

EXPERIMENTAL

The layout of the experimental field was explained in Part I. All the grass cut daily from the strips of the unlimed plots was chopped into small pieces and mixed into a sample labeled "Unlimed grass". An identical sample from the limed plots was labeled "Limed grass".

Fifteen one-year virgin female goats were selected for the experiment. They were given the parasite treatment: twelve grams of phenothiazine per os. The animals were randomized, one for each of fifteen pens (see photo), into five groups for the following three treatments: 1) goats fed with unlimed grass, 2) goats fed with limed grass, 3) goats fed with limed grass, and in addition, fed per os, with manganese sulphate.

The goat experiment covered an eleven-month period. It was started on October 19, 1944 and finished on September 15, 1945. The experiment was divided into four periods as follows:

1. Pre-feeding period (October 19–November 14, 1944)
2. Pre-gestation period (Nov. 15, 1944–January 15, 1945)
3. Gestation period (January 16–July 15, 1945)
4. Lactation period (July 16–September 15, 1945)

Eight pounds of the chopped "Unlimed grass" were fed to each of the goats in treatment No. 1. Eight pounds of the chopped "Limed grass" were fed to each of the goats in treatments No. 2 and No. 3. The feeding box (see photo) in each pen avoided the contamination of the grass with urine and excrement.

Each animal in treatment No. 3 was supplied daily in addition, per os, a solution containing 0.453 gram of manganese sulphate ($MnSO_4H_2O$) per liter, equivalent to .147 milligrams of manganese per milliliter. From November 15 to November 29, 1944, inclusive, and from February 3, 1945 to July 15, 1945, inclusive, each goat received daily, per os, 1 ml. of the manganese solution, but for the period between November 30, 1944 to February 2, 1945, inclusive, each goat received daily, per os, 1.5 ml. of the manganese solution. For the eight-month period, covering pre-gestation and gestation, each goat received 275.5 milliliters of the manganese solution equivalent to 40.5 milligrams of manganese.

The amount of residual grass left daily by each animal was also weighed. A composite sample from the "Unlimed Grass" and the "Limed Grass", was taken daily for moisture analysis. A record was kept of the amount of green and dry grass consumed by each animal.

Rain water from the two concrete wells besides greenhouse No. 5 in the Experiment Station Farm, was supplied daily to each animal. The water consumed daily, however, was very low. The mineral content of this water was as follows:

	parts per million
Calcium	4.0
Phosphorus	2.0
Iron	0.03
Magnesium	None
Manganese	None

Each goat was weighed three times in three consecutive days, around the middle and the end of each month.

To induce breeding of the goats at approximately the same time, each animal was given, per os, on January 29, 1945, 5 milligrams of diethyl stylbestrol.

METHODS OF ANALYSES

Blood samples were taken from each animal at the beginning of the "Pre-Feeding Period" on October 19, 1944; one month after the beginning of the "Pre-Gestation Period" in the middle of December 1945; and thereafter every middle of the month up to August 1945. About 10 ml. of blood were drawn from each animal by a direct puncture of the jugular vein: 2 ml. for the hematological test and 8 ml. for the chemical test. The 2 ml. blood portion was poured into a 10 ml. test tube containing a dry oxalate salt. This salt was prepared by adding 0.1 ml. of a mixed solution of 6 per cent ammonium oxalate and 4 per cent of potassium oxalate to each tube, and evaporating to dryness.

Hematological Test

A 0.1 ml. of the oxalated blood was used for the red-blood cell and white-blood cell counts. A 0.7 ml. portion of this blood was used for hematocrits and 0.1 ml. for hemoglobin.

Hemoglobin

Hemoglobin was determined in a fresh sample of cow's blood by the Van Slyke's method (2). Its content was found to be 9.04 grams hemoglobin per 100 ml. blood. A 1:25 solution was prepared by diluting 2 ml. of this cow's blood to 50 ml. with 0.1 per cent sodium carbonate solution. Transmittances of eleven dilute solutions, prepared from the 1:25 blood solution, are as follows:

SOLUTION NO.	ALIQUOT 1:25 BLOOD SOL	DILUTED WITH 0.1% SODIUM CARBONATE TO	DILUTION RATIO	HEMOGLOBIN MILLIGRAMS PER ML. BLOOD	TRANSMITTANCE
	ml.			*mg.*	%
1	6.00	18.00	1: 75.0	1.2053	15.0
2	5.00	20.00	1: 100.0	0.9040	22.5
3	5.00	23.00	1: 114.7	0.7881	26.7
4	5.00	26.67	1: 133.3	0.6782	31.3
5	5.00	32.50	1: 162.5	0.5563	38.1
6	2.50	20.00	1: 200.0	0.4520	45.1
7	2.50	26.67	1: 266.7	0.3390	54.8
8	1.25	20.00	1: 400.0	0.2260	66.8
9	1.25	26.67	1: 533.4	0.1695	73.6
10	1.25	40.00	1: 800.0	0.1130	81.0
11	1.25	80.00	1:1600.0	0.0565	90.0

The transmittance was determined in a Coleman spectrophotometer, model 11, using a PC-4 filter at a wave length of 540 mμ where maximum color absorption (figure 2) occurs. The sodium carbonate solution was used as reference. It gave a 99.1 per cent transmittance when the instrument was set at zero. The transmittance-concentration curve obtained for hemoglobin is reported in figure 1.

For the determination of hemoglobin in the unknown, 0.1 ml. of oxalated blood was diluted to 20 ml. with 0.1 per cent sodium carbonate solution. The transmittance of the colored solution was read in a Coleman spectrophotometer, model 11, using filter PC-4 at a wave length of 540 mμ. The transmittance from the curve (figure 1) multiplied by 20 gives grams of hemoglobin per 100 ml. blood.

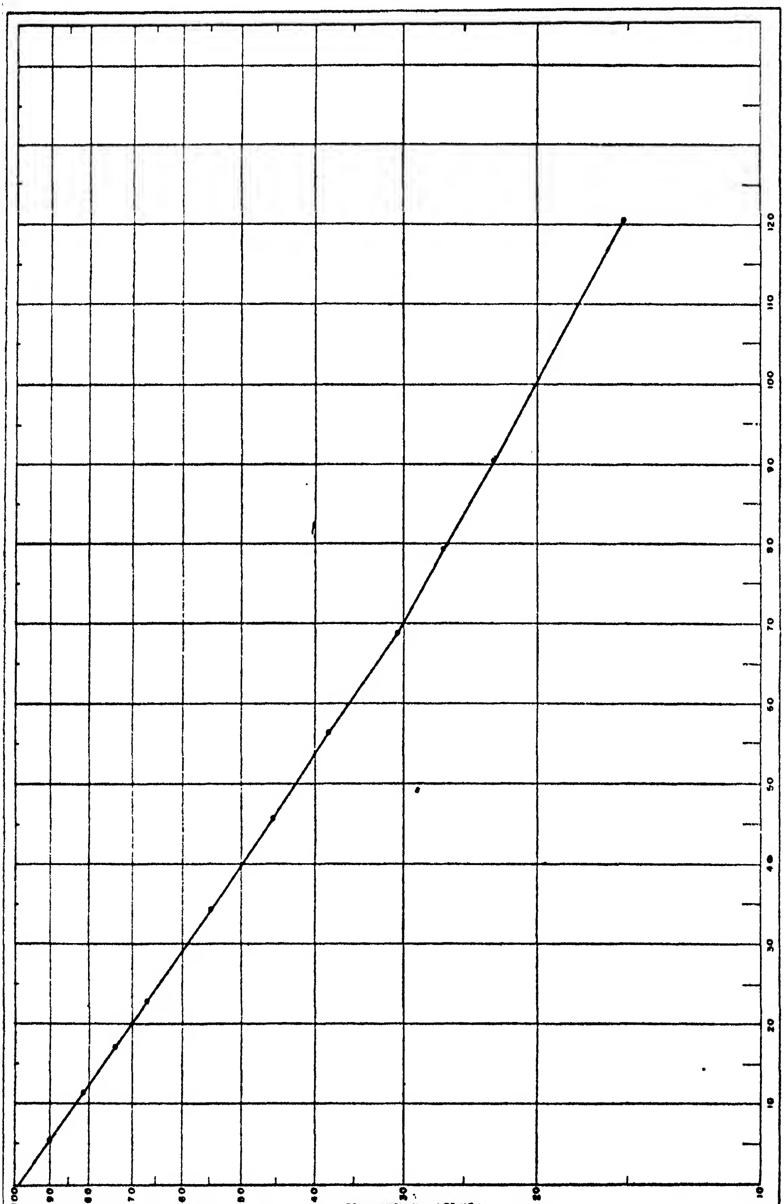


FIG. 1. Hemoglobin in blood. Curve obtained in Coleman spectrophotometer, Model 11, with filter PC-4, at a wave length of 540 mu, and 0.1 per cent sodium carbonate as reference solution. Abscissa represents milligrams of hemoglobin per milliliter blood. On the basis of 0.1 ml. blood diluted to 20 ml. with 0.1% $NaCO_3$; value in curve × 20 = grams hemoglobin per 100 ml. blood.

Chemical test

Iron. A sample of 0.5 ml. of oxalated blood was taken for the iron determination. The Wong's (5) modified method was used to develop the color and the transmittance was read in the Coleman spectrophotometer with filter PC-4 at a wave length of 480 m_μ using a reagent blank as the reference solution. The method used was as follows: Transfer with an Ostwald pipette 0.5 ml. of blood into a 50 ml. volumetric flask and introduce 2 ml. of iron-free concentrated sulphuric acid. Whirl the flask to agitate the mixture for 1 or 2 minutes. Add 2 ml. of saturated potassium persulfate solution and

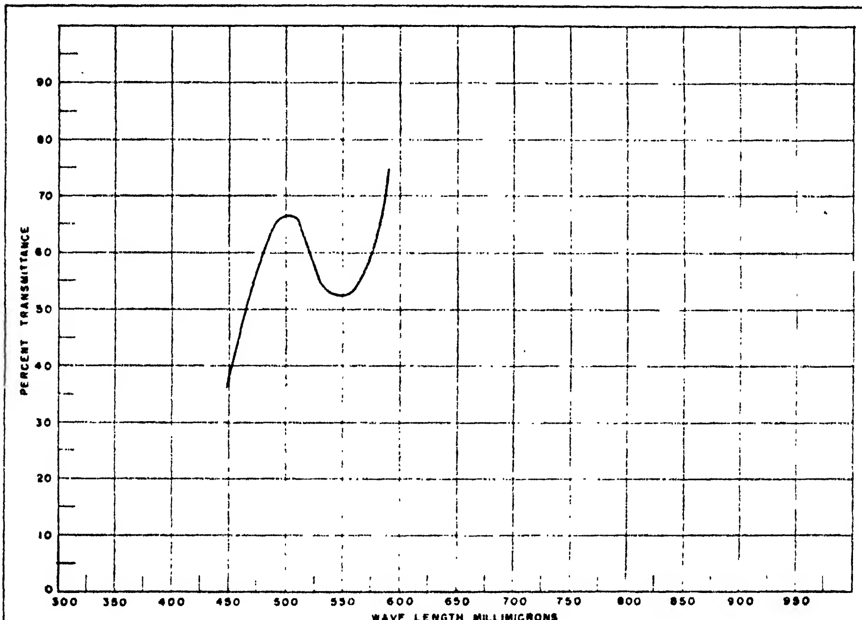


FIG. 2. Spectral-transmittance curve for hemoglobin. Maximum absorption of light at 540 millimicrons.

shake. Dilute to about 25 ml. with distilled water and add 2 ml. of 10 per cent sodium tungstate solution. Mix, cool to room temperature under the tap and then dilute to volume with distilled water. Stopper the flask and invert two or three times to effect thorough mixing. Filter through a dry filter paper into a clean, dry receiving vessel. Pipette 20 ml. of the clear filtrate into a large test-tube graduated at 20 ml. and 25 ml. The color was developed by adding 1 ml. of saturated potassium persulfate solution and 4 ml. of 3 N potassium sulfocyanate, KCNS, solution.

The iron standard solution was prepared as follows: Transfer 0.8635

gram of crystallyzed ferrous ammonium sulphate, $FeNH_4(SO_4)_2 \cdot 12H_2O$, to a small beaker and dissolve in about 50 ml. of water. Add 20 ml. of 10 per cent iron-free sulphuric acid. Transfer quantitatively to a liter volumetric flask and dilute to the liter mark with water. One ml. of this solution contains 0.1 mg. Fe. Dilute 10 ml. of this standard solution to 100 ml. with distilled water. One ml. contains 0.01 mg. Fe. The equivalent amount of this standard iron solution was measured in a pipette and poured into the 25 ml. test tube: 0.8 ml. of iron free concentrated sulphuric acid was added, and diluted to the 20 ml. mark with distilled water. Cool to room temperature under the tap, and develop the color as mentioned above, but develop it at the time of reading in the spectrophotometer to avoid fading. The transmittance obtained, for the various iron concentrations using a PC-4 filter, and a wave length of 480 mμ in the Coleman spectrophotometer, model 11, using the reagent blank as reference solution, was as follows:

IRON CONCENTRATION	TRANSMITTANCE
mg.	%
0.01	83.5
0.02	71.2
0.03	60.0
0.05	42.7
0.07	30.6
0.08	26.0
0.10	19.0

The slope of the standard cufve (figure 3) remains constant. Readings from curve give milligrams Fe per 100 ml. blood. The lower transmittance or maximum light absorption was obtained at a wave length of 480 mμ (figure 4).

Calcium and Phosphorus. The non-oxalated blood was centrifuged, immediately after drawn to avoid hemolysis, for 5 minutes at 2800 r.p.m. in an International clinical centrifuge. The fibrin sealing the plasma was loosened carefully with a wooden rod. The plasma was poured down, or was centrifuged again if necessary, to avoid hemolysis since the red-blood cells of goat's blood are quite minute (diameter = 4.1 microns) and fragile.

Calcium. Calcium in blood serum was determined by the method of Roe and Kahn (4) using a Klett-Summerson photoelectric colorimeter No. 2141, test-tube model, with red filter 66, at a wave length range 640–700 mμ, reading against a reagent blank. The procedure for the blank, unknown, and standard, was as follows:

Unknown. Add 1 volume of serum to 4 volumes of 10% trichloroacetic acid in a small flask and shake well. Pour onto a dry calcium-free filter

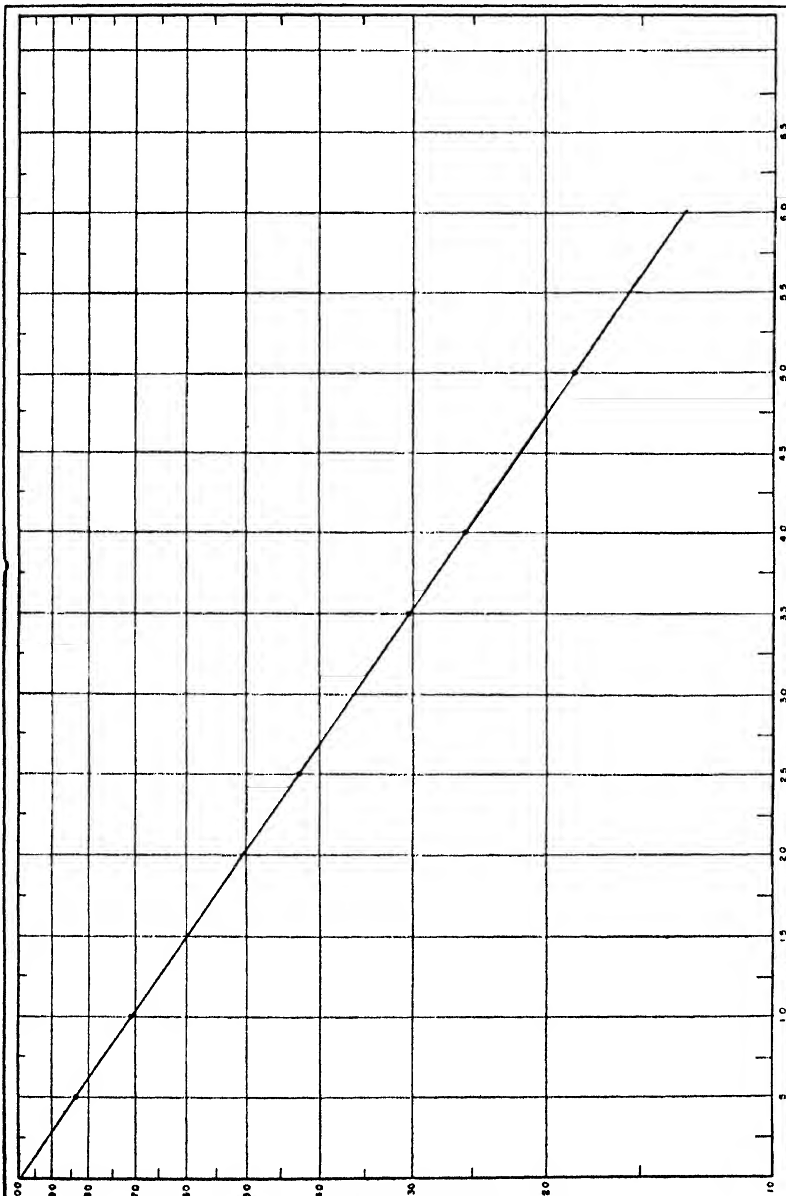


FIG. 3. Iron in blood curve obtained in Coleman spectrophotometer, Model 11, with filter PC-4, at a wave length of 480 mu, and reagent blank as reference solution. Abscissa represents milligrams of iron as Fe. Readings from curve give milligrams Fe per 100 ml. blood.

paper (Whatman No. 42 or its equivalent) and collect the filtrate in a dry flask. Place 5.0 ml. of the filtrate in a graduated 15 ml. conical centrifuge tube and add 1.0 ml. of 25% sodium hydroxide solution, with mixing by lateral shaking. Allow to stand for 5 minutes, then add 1.0 ml. of 5% tri-sodium phosphate solution, mix well by lateral shaking, and set aside for an hour. At the end of this time, centrifuge for 2 minutes, and pour off the supernatant fluid, allowing the tube to drain in an inverted position for 2 minutes. Wipe the mouth of the tube dry with a clean cloth. Wash the

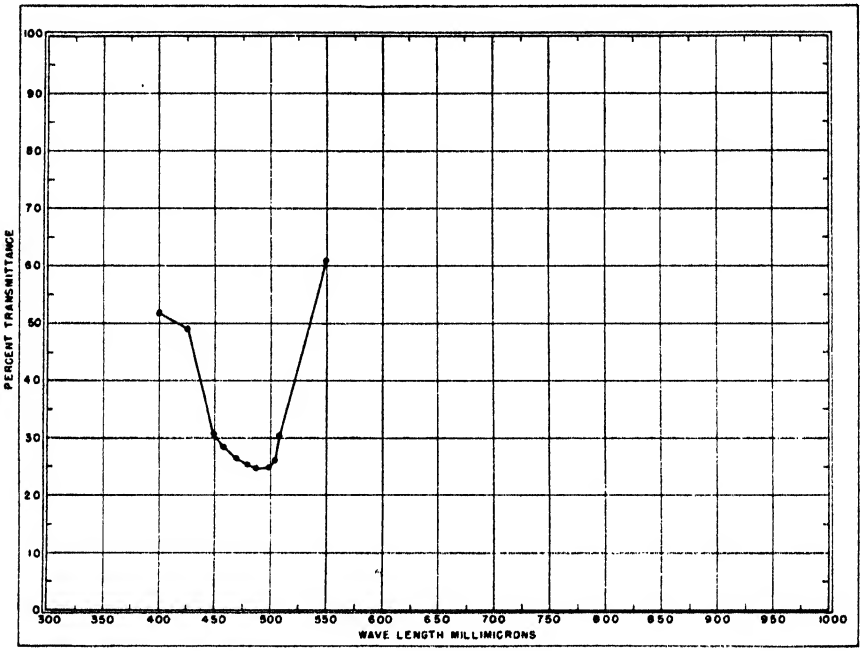


FIG. 4. Spectral-transmittance curve for iron as per method of blood. Maximum absorption of light at a wave length of 480 millimicrons.

precipitate with 5 ml. of alkaline-alcoholic wash reagent (to 10 ml. of amyl alcohol, add 58 ml. of ethyl alcohol, and mix; dilute to 100 ml. with water; add 2 drops of 1 per cent phenolphthalein solution and then, drop by drop, add sufficient 5 per cent sodium hydroxide solution to a distinct pink color; (a few drops should be sufficient); delivered from a pipette with a fine tip, blowing the first portion of wash fluid against the precipitate with such force as to break it up, and using the remainder of wash fluid to rinse down the sides of the centrifuge tube. If necessary use a stirring rod to break up the precipitate. Centrifuge for 2 minutes, pour off the supernatant fluid and allow the tube to drain as before. After draining, wipe the mouth of the

tube dry, and add 2.0 ml. of molybdate reagent (dissolve 25 grams of c.p. ammonium molybdate in 200 ml. water, and pour into a one-liter volumetric flask containing 500 ml. of 10 normal sulfuric acid; dilute to the mark and mix); to dissolve the precipitate and form phosphomolybdate from the phosphate present. After a complete solution of the precipitate, which may be hastened by shaking or stirring, dilute to 10.0 ml. with distilled water, and mix well. Transfer a 5.0 ml. portion from the centrifuge tube to a colorimeter tube and add 0.4 ml. of the aminonaphtholsulfonic acid reagent. Dilute with water to 10.0 ml., mix, and read in the colorimeter after five minutes setting the colorimeter at zero with reagent blank.

Blank. Treat a 5.0 ml. portion of distilled water with 1 ml. of molybdate reagent and 0.4 ml. of aminonaphtholsulfonic acid reagent (weigh 0.125 gram of c.p. 1-amino-2-naphthol-4-sulfonic acid, Eastman Kodak 360, into a 250 ml. beaker containing 50 ml. of 15 per cent sodium bisulfite and 1 ml. of 20 per cent sodium sulfite; shake until dissolved; add a little more of the sodium sulfite solution if necessary to bring the powder into solution; add a little more of the sodium sulfite solution, but an excess should be avoided; keep in a brown bottle away from light; this solution should be prepared fresh every two weeks); and dilute to the 10.0 ml. mark. Set the colorimeter at zero with this reagent blank.

Standard. Treat a 5.0 ml. portion of the standard phosphate solution with 1 ml. of molybdate reagent, add 0.4 ml. of aminonaphtholsulfonic acid reagent, dilute with water to the 10.0 ml. mark, and mix. Read in the colorimeter after 5 minutes. 1 ml. standard phosphate solution = 0.001 milligram P $= \frac{9.67}{5}$ or 1.934 milligrams Ca per 100 ml. blood serum. The readings obtained for the standard curve, after setting instrument at zero with reagent blank, were as follows:

STANDARD P SOLUTION	PHOTOCOLORIMETER READINGS	Ca PER 100 ML. SERUM	SLOPE OF CURVE
mg.		*mg.*	
0.002	76	3.87	0.05092
0.004	155	7.74	0.04994
0.005	192	9.67	0.05036
0.006	228	11.60	0.05088
0.008	310	15.47	0.04990

The slope of the standard curve remains constant. Its average value or factor (figure 5) equals 0.05040. Reading of unknown in photocolorimeter × 0.05040 equals milligrams of calcium per 100 milliliters blood serum.

Inorganic Phosphorus. Inorganic phosphorus in blood serum was deter-

mined by the method explained in Levinson & MacFate (3) but using a Coleman spectrophotometer, model 11, with filter PC-4 and a wave length of 600 mμ (figure 7), reading against a reagent blank. The procedure was as follows: Transfer 4 ml. of 10 per cent trichloracetic acid to a small flask and add 1 ml. of the blood serum with shaking. Larger volumes of the serum may be used in the same proportion. Shake well, let stand for 1 to 2 minutes, and filter through a phosphorus-free filter paper. If small quantities of material are used, pour the mixture into a centrifuge tube, centri-

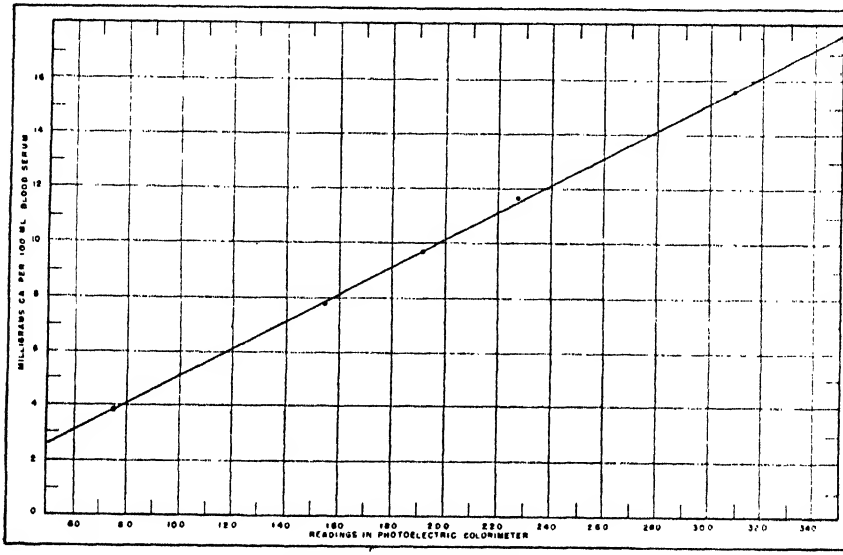


FIG. 5. Calcium in blood serum. Curve obtained in Klett-Summerson photoelectric colorimeter, No. 2141, test tube model, with red filter 66, at a wave length range 640–700 mu, and the instrument at zero with reagent blank. Average slope of curve = 0.0504. Readings of curve X0.0504 = milligrams of Ca per 100 ml. blood serum.

fuge for a few minutes and filter the clear supernatant fluid through 4.25 centimeter filter paper in a small funnel. Transfer 2 ml. of the filtrate to a 50 ml. Erlenmeyer flask. Add 12 ml. of distilled water, 4 ml. of the molybdic-sulfuric acid reagent A (50 ml. of 10 normal sulphuric acid added to 50 ml. of 7.5 per cent sodium molybdate solution), and 2 ml. of dilute stannous chloride solution (dissolve 10 grams of stannous chloride in 25 ml. of concentrated hydrochloric acid; preserve this stock solution in a brown bottle; dilute 1 ml. of stock solution to 200 ml. with water; preserve in a brown bottle; this dilute solution keeps for 5 days, but is better if prepared fresh each time). Mix well and after 15 minutes read in spectrophotometer.

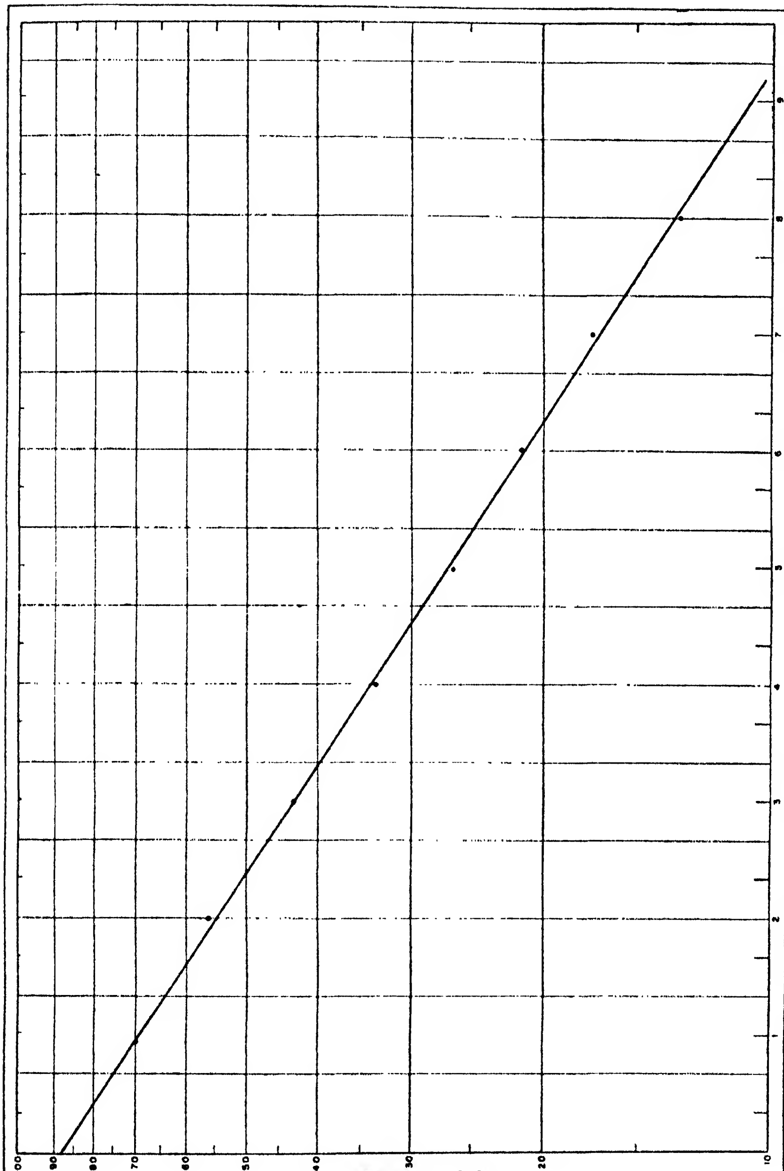


FIG. 6. Inorganic phosphorus in blood serum. Curve obtained in Coleman spectrophotometer, Model 11, with filter PC-4, at a wave length of 600 mu, and the reagent blank as reference solution. Abscissa represents milligrams phosphorus (P) per 100 ml. serum. Slope of standard curve was not found to be constant. Run at least three standards to check slope.

Calibration Curve. Dilute 20 ml. of standard phosphorus solution (1 ml. = 0.01 mg. P) to 25 ml. with distilled water. Dilute to 14 ml. Add 4 ml.

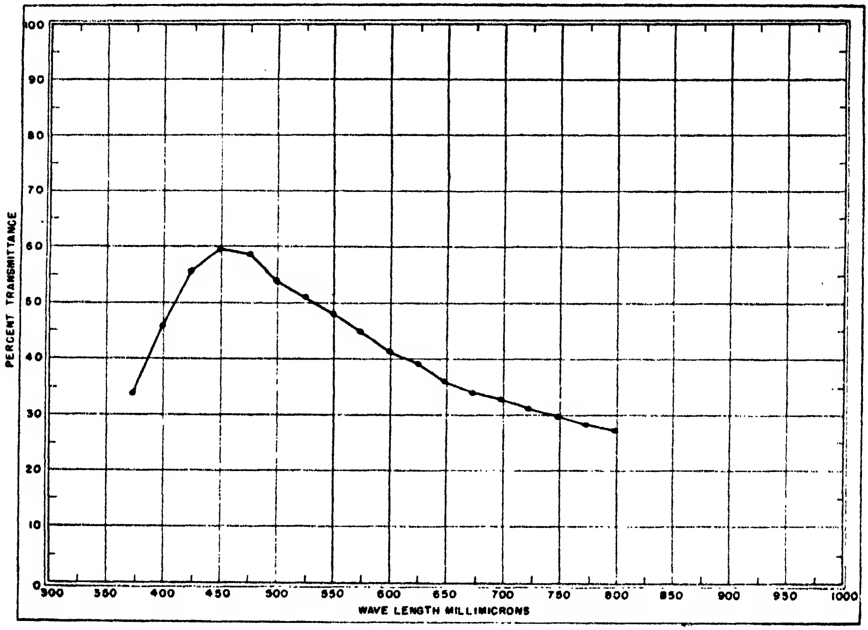


FIG. 7. Special-transmittance curve for phosphorus as per method of blood serum. The PC-4 filter was used for wave lengths, from 350 to 700 mu, and the PC-5 filter, from 700–800 mu.

of the molybdic-sulfuric acid reagent A and 2 ml. of the stannous chloride solution. Read after 15 minutes and plot in semi-log paper.

The following readings were obtained for transmittance:

P-STANDARD	P IN STANDARD	P PER 100 ML. SERUM	TRANSMITTANCE
ml.	*mg.*	*mg.*	%
0.5	0.004	1	70.0
1.0	0.008	2	56.3
1.5	0.012	3	43.7
2.0	0.016	4	34.4
2.5	0.020	5	27.0
3.0	0.024	6	21.9
3.5	0.028	7	17.5
4.0	0.032	8	13.2

Prepare three sets of standards with 1, 5, 8 mgm. P per 100 ml. serum, respectively, simultaneously with the unknown, since it was found that the slope of the standard curve (figure 6) is not constant.

PRESENTATION OF DATA AND DISCUSSION

The monthly weights in pounds per goat and the average monthly weights for the five goats in the treatments: unlimed grass, limed grass, and limed grass plus manganese, are reported for a period of eleven months in table 1. The changes in average weight of the animals in each treatment before and after the pre-gestation period and after the gestation period are condensed in table 2. There was no significant increase in the weight of the goats for the two-month pre-gestation period. However, there was a higher significant decrease of about 8.5 pounds in weight after the six-month gestation period.

The total amount in pounds of the Para-Carib grass mixture and minerals, on the dry basis, eaten by each goat and the average eaten by the five goats in each of the three treatments during the pre-gestation and gestation periods are reported in table 3. The per cent of calcium, phosphorus, manganese, iron and magnesium used for the calculation is that reported previously (1) in part I for the third and fourth grass crops, respectively, in the field at the time of sampling. The total amount of dry grass eaten in the pre-gestation and gestation periods and the total minerals eaten for both periods by the five goats in each treatment are condensed in table 4.

There were significant differences for the pre-gestation period between the grass intake of the goats under the three treatments. The goats fed with unlimed grass ate less than those fed with limed grass. However, for the gestation period the difference for the grass intake between the treatments was not significant.

The average daily grass and mineral intake, in grams per five goats, of about 52 pounds in average weight, is reported in table 5. These data were calculated for a total of 243 days covering the pre-gestation and gestation periods.

The average intake of unlimed grass was about 6 pounds of dry grass per five goats per day and of limed grass was about 7 pounds for animals weighing around 52 pounds.

The goats fed with limed grass received daily about 4 grams more of calcium, 2 grams more of phosphorus, 0.2 grams more of iron, 1 gram more of magnesium, and about 0.2 grams less manganese than the goats fed with unlimed grass. The additional manganese added, per os, to each goat fed with the limed grass, which amounted to 41 milligrams of manganese for the 243 days covering the pre-gestation and gestation periods, was too small to account for an increase in the manganese content of the limed grass.

The average hemoglobin, iron in blood, calcium and phosphorus in blood serum, and blood count per goat in each treatment is reported in table 6. There were no significant differences in the pre-gestation period between the mean red or white-blood cells, the hematocrits, the hemoglobin and iron

TABLE 1

Monthly weights of goats fed with unlimed grass and limed grass with or without extra manganese, for a ten-month period

GROUP	TREATMENT	ANIMAL NUMBER	1944		1945								
			Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
			lb.	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*
I	Unlimed grass	81	57.2	56.7	54.8	53.5	51.3	49.5	46.2	48.8	D*	—	—
		90	69.5	68.0	68.8	64.0	64.5	60.2	59.3	54.2	57.7	60.3	58.2
		91	49.5	50.7	49.3	49.0	48.8	46.5	44.8	44.8	43.3	45.2	45.7
		92	48.0	50.0	47.8	45.2	42.7	39.8	37.0	40.0	38.8	39.8	40.3
		94	52.9	54.8	54.0	51.0	52.3	48.8	47.0	48.8	48.0	51.8	51.5
Ave.			55.4	56.0	55.0	52.5	51.9	49.0	46.9	47.3	47.0	49.3	48.9
II	Limed grass	72	39.3	43.3	43.7	41.5	38.7	37.0	35.0	37.3	39.2	39.2	40.5
		80	63.0	64.5	65.8	66.8	63.7	61.3	59.0	63.3	59.7	57.0	53.7
		83	66.8	66.8	67.5	64.5	62.3	57.2	57.3	59.2	44.5	50.2	51.2
		95	52.0	54.2	51.0	49.7	45.5	44.3	39.5	46.5	44.2	45.8	42.0
		97	55.5	55.8	54.8	52.3	50.8	45.5	43.5	48.0	45.8	48.8	48.5
Ave.			55.3	56.9	56.6	55.0	52.1	49.0	46.9	50.9	46.7	48.7	47.2
III	Limed grass & manganese	78	63.5	62.5	63.0	63.2	60.8	58.7	55.8	59.5	57.5	57.5	54.8
		84	49.5	54.2	51.0	50.3	48.3	42.7	42.3	46.7	42.0	45.0	40.0
		87	54.0	54.5	52.0	53.5	52.5	51.8	47.8	51.0	39.8	45.3	48.0
		88	68.2	71.0	65.8	66.7	62.8	61.2	57.3	60.5	60.2	60.0	59.5
		93	46.5	48.2	44.5	45.3	43.3	39.2	37.5	41.5	39.7	43.2	39.5
Ave.			56.3	58.1	55.3	56.0	53.5	50.7	48.1	51.8	47.8	50.2	48.4

* D = died.

TABLE 2

Average weights of the goats, before and after the treatment

TREATMENT	PRE-GESTATION PERIOD		GESTATION PERIOD
	Before	2 months after	6 months after
	lb.	*lb.*	*lb.*
Unlimed grass	55.4	55.0	47.0
Limed grass	55.3	56.6	46.7
Limed grass plus manganese	56.3	55.3	47.8

in the blood, and the calcium and phosphorus in the serum of the goats in the three treatments.

The goats were healthy and vigorous at the end of the pre-gestation pe-

TABLE 3

Grass and minerals eaten by goats during pre-gestation and gestation periods (dry basis), pounds

TREATMENT	GOAT NO.	THIRD CROP	FOURTH CROP	TOTAL	CALCIUM (Ca)			PHOSPHORUS (P)			MANGANESE (Mn)			IRON (Fe)			MAGNESIUM (Mg)		
					a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Unlimed grass	81	162	116	278	.33	.34	.67	.45	.28	.73	.03	.04	.07	.03	.01	.04	.30	.24	.54
	90	176	163	339	.35	.47	.82	.48	.39	.87	.03	.04	.07	.04	.02	.06	.32	.33	.65
	91	156	152	308	.31	.44	.75	.43	.36	.79	.02	.04	.06	.03	.02	.05	.29	.31	.60
	92	130	124	254	.26	.36	.62	.36	.30	.66	.02	.03	.05	.03	.02	.05	.24	.26	.50
	94	162	158	320	.33	.46	.79	.45	.38	.83	.03	.04	.07	.03	.02	.05	.30	.33	.63
Total		786	713	1499	1.58	2.07	3.65	2.17	1.71	3.88	.13	.19	.32	.16	.09	.25	1.45	1.47	2.92
Limed grass	72	160	148	308	.51	.50	1.04	.49	.43	.92	.01	.03	.04	.03	.04	.07	.35	.31	.66
	80	195	170	365	.65	.57	1.22	.59	.50	1.09	.02	.03	.05	.03	.04	.07	.43	.35	.78
	83	194	154	348	.65	.52	1.17	.59	.45	1.04	.02	.03	.05	.03	.04	.07	.43	.32	.75
	95	183	132	315	.61	.45	1.06	.56	.39	.95	.02	.02	.04	.03	.03	.06	.41	.28	.69
	97	184	147	331	.62	.50	1.12	.56	.43	.99	.02	.03	.05	.03	.04	.07	.41	.31	.72
Total		916	751	1667	3.07	2.54	5.61	2.79	2.20	4.99	.09	.14	.23	.15	.19	.34	2.03	1.57	3.60
Limed grass plus manganese	78	188	196	384	.63	.66	1.29	.57	.57	1.14	.02	.04	.06	.03	.05	.08	.42	.41	.83
	84	159	139	298	.53	.47	1.00	.49	.41	.90	.01	.03	.04	.03	.03	.06	.35	.29	.64
	87	188	169	357	.63	.57	1.20	.57	.49	1.06	.02	.03	.05	.03	.04	.07	.42	.35	.77
	88	206	189	395	.69	.64	1.33	.63	.55	1.18	.02	.03	.05	.03	.05	.08	.46	.39	.85
	93	154	133	287	.52	.45	.97	.47	.39	.86	.01	.02	.03	.03	.03	.06	.34	.28	.62
Total		895	826	1721	3.00	2.79	5.79	2.73	2.41	5.14	.08	.15	.23	.15	.20	.35	1.99	1.72	3.71

a = third crop, b = fourth crop, c = total.

riod; but were skinny, bony, and weak at the end of the gestation period (see photo). All of them, irrespective of treatment, showed at the end of gestation a reduction in red- and white-blood cells, in hematocrits, in hemoglobin, and in blood iron. However, no change was evidenced in the calcium and phosphorus of the blood serum.

Of the total of fifteen goats; ten aborted, and one died. Each of two goats, fed with limed grass, delivered a weak kid but did not produce milk

TABLE 4

Total dry grass and minerals eaten by the five goats, in each respective treatment, covering the eighth-month pre-gestation and gestation periods

TREATMENT	DRY GRASS EATEN			MINERALS EATEN				
	Pre-gestation period, 2-months	Gestation period, 6-months	Total, 8-months	Ca	P	Mn	Fe	Mg
	lb.	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*
Unlimed grass	344	1155	1499	3.65	3.88	0.32	0.25	2.92
Limed grass	419	1258	1677	5.61	4.99	0.23	0.34	3.60
Limed grass plus 203 milligrams of manganese supplied per os to 5 goats	404	1317	1721	5.79	5.14	0.23	0.35	3.71

TABLE 5

Average intake of dry grass in pounds and minerals in grams per day per group of five goats of about 52 pounds each

TREATMENT	DRY GRASS EATEN	MINERALS EATEN				
		Ca	P	Mn	Fe	Mg
	lb.	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*
Unlimed grass	6.17	6.8	7.2	0.60	0.47	5.5
Limed grass	6.90	10.5	9.3	0.43	0.64	6.7
Limed grass plus manganese	7.08	10.8	9.6	0.43	0.65	6.9

even for the newborn. Stylbestrol, at the rate of 5 milligrams per os, which was given to the goats to induce even ovulation, might have been the cause of upsetting their endocrine balance and affecting in general the health of the animal. A marked increase was noticed in the calcium and phosphorus contents of the blood serum one-month after the stylbestrol application (table 7).

Iron combined with hemoglobin and uncombined are reported in table 8. This table contains data for 147 determinations made for iron and hemo-

globin in goat's blood taken monthly for a period of nine months, from each of the fifteen goats in the experiment. The color of the iron was developed by Wong's (5) method, and both, the iron and hemoglobin were determined separately in the spectrophotometer, as already reported. The combined iron in table 8 was calculated by multiplying the hemoglobin by the factor 3.35, as proposed by Wong (5) on the basis that

TABLE 6

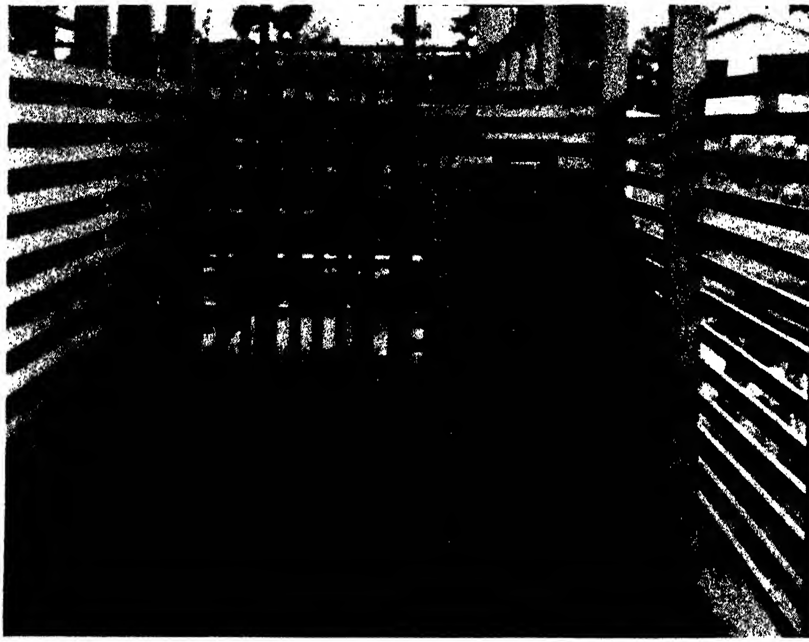
Hematological data, iron in blood, calcium and phosphorus in blood serum, for goats in each treatment

TREATMENT	PERIOD	RED BLOOD CELLS PER CU. MM.	WHITE BLOOD CELLS PER CU. MM.	HEMATOCRITS	HEMOGLOBIN	Fe IN BLOOD	Ca IN SERUM	P IN SERUM
		$\times 10^3$		% vol.	gm. %*	mg. %†	mg. %	mg. %
Unlimed grass	Before pregestation	17,626	19,980	31.9	10.5	48.2	11.4	4.9
	End of pregestation	16,894	15,980	30.2	10.1	37.1	12.5	4.0
	End of gestation	15,043	13,475	25.3	8.2	35.4	13.8	4.2
Limed grass	Before pregestation	19,680	19,560	34.2	11.5	51.2	10.6	5.5
	End of pregestation	17,646	18,880	32.5	10.7	39.0	12.2	4.2
	End of gestation	14,662	13,790	23.7	7.9	34.2	14.1	5.2
Limed grass plus manganese	Before pregestation	20,508	16,490	35.7	11.8	51.9	9.9	6.2
	End of pregestation	18,206	15,690	33.0	11.1	40.1	10.2	5.9
	End of gestation	12,624	13,910	22.5	7.6	34.1	13.9	5.2

* Grams hemoglobin per 100 ml. blood.
† Milligrams Fe per 100 ml. blood.

hemoglobin contains 0.0335 per cent iron as Fe. Results in table 8 reveal that considerable of the iron in the blood is not combined with hemoglobin. The uncombined iron varied from 0.1 to 19.9 milligrams per 100 milliliters of blood in 129 blood tests. In 18 tests the iron calculated from the hemoglobin was from 0.79 to 13.0 milligrams per 100 milliliters of blood higher than that found. The low iron content of the blood and the iron deficit in the hemoglobin occurred at regular intervals; the first, at the fifth month period of the experiment; the second, at the ninth month period.

Wong's proposal for calculating hemoglobin from the iron content of the blood does not give, therefore, a true value for hemoglobin, nor does the calculation of blood iron from the hemoglobin content gives a true value for the iron in blood.



A GOAT IN ITS PEN EATING GRASS FROM THE FEEDING BOX
Note poor physical appearance of goat during the gestation period

TABLE 7

Mean calcium and phosphorus contents of blood serum from fifteen female goats before and after stylbestrol application

MINERAL	STYLBESTROL APPLICATION		
	Before	One month after	Two months after
	%	%	%
Calcium, Ca	11.6	17.8	11.6
Phosphorus, P	4.7	6.2	5.7

It has been mentioned that the animals sustained their weight and were healthy and vigorous at the end of the pre-gestation period; but were skinny, bony, and weak at the end of the gestation period. A reduction in red and white blood cells, in hematocrits, in hemoglobin and blood iron,

TABLE 8

Hemoglobin; iron calculated from hemoglobin, iron determined, and uncombined iron, in blood samples taken monthly for a period of nine months from fifteen female goats

TREATMENT	GOAT NO.	DATE	HEMOGLOBIN	CALCULATED Fe Hb × 3.35	DETERMINED Fe	UNCOMBINED Fe
		mo.	*g/100 ml.*	*mg./100 ml.*	*mg./100 ml.*	*mg./100 ml.*
1. Goats receiving unlimed grass	81	0	10.20	34.17	46.8	12.63
		1	9.96	33.37	42.7	9.33
		2	9.24	30.95	35.3	4.35
		3	9.00	30.15	35.6	5.45
		4	9.62	32.23	36.8	4.57
		5	9.80	32.83	34.3	1.47
		6	8.32	27.87	33.2	5.33
		7	6.00	20.10	23.3	3.20
		8	—	—	—	—
		9	—	—	—	—
	90	0	11.50	38.53	49.2	10.67
		1	10.20	34.17	44.8	10.63
		2	9.82	32.90	36.2	3.30
		3	9.96	33.37	38.5	5.13
		4	8.30	27.81	35.2	7.39
		5	9.20	30.82	31.4	.58
		6	8.64	28.94	33.2	4.26
		7	6.60	22.11	25.7	3.59
		8	7.44	24.92	33.6	8.68
		9	7.40	24.79	17.5	−7.29
	91	0	9.20	30.82	50.7	19.88
		1	8.66	29.01	43.7	14.69
		2	8.66	29.01	32.5	3.49
		3	10.08	33.77	39.5	5.73
		4	8.90	29.82	38.2	8.38
		5	9.00	30.15	31.2	1.05
		6	8.20	27.47	32.4	4.93
		7	7.38	24.72	29.5	4.78
		8	8.38	28.07	37.5	9.43
		9	8.00	26.80	17.7	−9.10
	92	0	10.50	35.18	47.0	11.82
		1	10.40	34.84	44.8	9.96
		2	11.00	36.85	40.5	3.65
		3	9.98	33.43	38.5	5.07
		4	9.02	30.22	35.3	5.08
		5	9.70	32.50	33.0	.50
		6	8.00	26.80	32.5	5.70
		7	7.78	26.06	28.0	1.94
		8	7.90	26.47	33.8	7.33
		9	7.94	26.60	16.8	−9.80

TABLE 8—*Continued*

TREATMENT	GOAT NO.	DATE	HEMOGLOBIN	CALCULATED Fe Hb × 3.35	DETERMINED Fe	UNCOMBINED Fe
		mo.	*g/100 ml.*	*mg./100 ml.*	*mg./100 ml.*	*mg./100 ml.*
1. Goats receiving unlimed grass —*Continued*	94	0	11.00	36.85	47.5	10.65
		1	11.54	38.66	48.5	9.84
		2	11.54	38.66	40.8	2.14
		3	11.22	37.59	43.3	5.71
		4	9.68	32.43	38.7	6.27
		5	10.80	36.18	32.6	−3.58
		6	10.02	33.57	41.6	8.03
		7	8.16	27.34	—	—
		8	9.20	30.82	36.5	5.68
		9	9.00	30.15	22.8	−7.35
2. Goats receiving limed grass	72	0	12.10	40.54	55.5	14.96
		1	10.80	36.18	43.0	6.82
		2	10.40	34.84	37.7	2.86
		3	11.00	36.85	41.0	4.15
		4	10.16	34.04	42.0	7.96
		5	9.60	32.16	33.6	1.44
		6	9.02	30.22	35.5	5.28
		7	7.00	23.45	28.7	5.25
		8	8.30	27.81	36.4	8.59
		9	7.76	26.00	13.0	−13.00
	80	0	11.80	39.53	49.5	9.97
		1	10.56	35.38	42.5	7.12
		2	11.30	37.86	41.3	3.44
		3	11.38	38.12	42.5	4.38
		4	9.96	33.37	39.7	6.33
		5	10.00	33.50	33.6	.10
		6	9.84	32.96	36.8	3.84
		7	7.46	24.99	40.0	15.01
		8	9.00	30.15	42.3	12.15
		9	8.24	27.60	19.2	−8.40
	83	0	11.00	36.85	54.3	17.45
		1	10.80	36.18	42.7	6.52
		2	10.20	34.17	36.7	2.53
		3	10.80	36.18	41.0	4.82
		4	10.20	34.17	43.4	9.23
		5	10.80	36.18	36.4	.22
		6	9.24	30.95	35.7	4.75
		7	6.80	22.78	24.2	1.42
		8	7.20	24.12	28.0	3.88
		9	7.00	23.45	17.3	−6.15

TABLE 8—*Continued*

TREATMENT	GOAT NO.	DATE	HEMOGLOBIN	CALCULATED Fe Hb × 3.35	DETERMINED Fe	UNCOMBINED Fe
		mo.	*g/100 ml.*	*mg./100 ml.*	*mg/100 ml.*	*mg./100 ml.*
2. Goats receiving limed grass—*Continued*	95	0	11.00	36.85	49.1	12.25
		1	11.10	37.19	47.0	9.81
		2	10.60	35.51	40.0	4.49
		3	9.92	33.23	39.5	6.27
		4	7.86	26.33	32.7	6.37
		5	9.00	30.15	30.3	.15
		6	7.50	25.13	31.0	5.87
		7	6.80	22.78	28.1	5.32
		8	7.04	23.58	30.5	6.92
		9	6.16	20.64	15.2	−5.44
	97	0	11.40	38.19	47.5	9.31
		1	12.56	42.08	54.0	11.92
		2	10.76	36.05	39.4	3.35
		3	10.08	33.77	39.8	6.03
		4	9.62	32.23	38.7	6.47
		5	9.60	32.16	31.5	−.66
		6	9.50	31.83	34.4	2.57
		7	7.38	24.72	27.8	3.08
		8	--	—	33.8	-
		9	7.90	26.47	18.7	−7.77
3. Goats receiving limed grass plus manganese	78	0	13.20	44.22	61.5	17.28
		1	12.20	40.87	50.5	9.63
		2	12.40	41.54	45.0	3.46
		3	12.18	40.80	46.2	5.40
		4	9.80	32.83	44.0	11.17
		5	12.10	40.54	39.8	−.74
		6	11.06	37.05	41.5	4.45
		7	8.56	28.68	33.8	5.12
		8	8.60	28.81	30.0	1.19
		9	7.92	26.53	18.8	−7.73
	84	0	10.40	34.84	47.6	12.76
		1	12.70	42.55	54.8	12.25
		2	12.20	40.87	43.5	2.63
		3	12.38	41.47	44.8	3.33
		4	8.96	30.02	35.8	5.78
		5	10.40	34.84	35.6	.76
		6	10.20	34.17	40.4	6.23
		7	8.56	28.68	32.8	4.12
		8	7.60	25.46	43.3	17.84
		9	3.60	12.06	5.5	−6.56

TABLE 8—*Continued*

TREATMENT	GOAT NO.	DATE	HEMOGLOBIN	CALCULATED Fe Hb × 3.35	DETERMINED Fe	UNCOMBINED Fe
		mo.	*g/100 ml.*	*mg./100 ml.*	*mg./100 ml.*	*mg./100 ml.*
3. Goats receiving limed grass plus manganese—*Continued*	87	0	11.04	36.98	49.0	12.02
		1	10.10	33.84	40.0	6.16
		2	9.36	31.36	36.2	4.84
		3	8.40	28.14	34.6	6.46
		4	9.00	30.15	37.8	7.65
		5	9.40	31.49	30.7	−.79
		6	8.10	27.14	31.7	4.56
		7	6.18	20.70	24.4	3.70
		8	5.86	19.63	25.3	5.67
		9	5.14	17.22	12.5	−4.72
	88	0	12.80	42.88	52.5	9.62
		1	11.80	39.53	47.0	7.47
		2	11.40	38.19	38.5	.31
		3	9.92	33.23	39.6	6.37
		4	10.06	33.70	38.7	5.00
		5	9.40	31.49	34.5	3.01
		6	8.48	28.41	31.4	2.99
		7	7.46	24.99	30.3	5.31
		8	8.60	28.81	37.2	8.39
		9	7.60	25.46	18.6	−6.86
	93	0	11.50	38.53	49.0	10.47
		1	10.90	36.52	43.5	6.98
		2	10.34	34.64	37.4	2.76
		3	9.60	32.16	39.0	6.84
		4	9.80	32.83	38.5	5.67
		5	9.90	33.17	33.6	.43
		6	8.90	29.82	35.1	5.28
		7	7.60	25.46	29.3	3.84
		8	7.20	24.12	34.5	10.38
		9	6.40	21.44	15.2	−6.24

was also reported for the gestation period. It has also been mentioned that two thirds of the goats aborted and that the two goats delivering weak kids produced no milk. Presumably the stylbestrol application upset the endocrine balance and affected the general health of the animals. All indications pointed to malnutrition of the goats during gestation, probably due to an inadequate protein intake.

A composite sample of the grass fed to the animals was not collected during the pre-gestation and gestation periods. The mineral intake for the goats was calculated from the mineral composition of the grass at time of sampling (table 4). The protein intake (table 9) was calculated similarly.

During the pre-gestation period the goats were fed exclusively with grass from the third crop (1) that received a nitrogen application at the rate of 500 pounds of ammonium sulphate per acre. The protein content of this grass at time of sampling, or 36 days after nitrogen application, was 11.2 per cent.

During the gestation period the goats were fed 72 days with high protein grass from the third crop and 110 days with a low protein grass from the fourth crop that received no nitrogen fertilization.

The daily intake of protein per goat for the pre-gestation period was estimated to be 0.143 pounds or about 65 grams, and for the gestation period was .089 pounds or about 40 grams (table 9). The goats ate per day about the same amount of grass in the pre-gestation and gestation periods, but the

TABLE 9

Estimated protein intake per goat per day during the pre-gestation and gestation periods

PERIOD	TIME OF PERIOD	AMOUNT OF GRASS EATEN PER GOAT PER		PROTEIN CONTENT OF GRASS AT TIME OF SAMPLING	ESTIMATED AMOUNT OF PROTEIN EATEN PER GOAT PER DAY
		Period	Day		
	days	*lbs.*	*lbs.*	%	*lb.*
Pre-gestation	61	77.8	1.28	11.2	0.143
Gestation	72	98.4	1.37	11.2	0.153
	110	150.3	1.37	3.5	0.048
	182	248.7	1.37		0.089

daily intake of protein was 25 grams less in the gestation period. This protein deficiency might have been the cause for the malnutrition of the goats during the gestation period.

CONCLUSION

Female goats kept in their pens, and fed exclusively with a mixture of unlimed and limed Para or "Malojillo" grass (*Panicum purpurascens*) and Carib or "Malojilla" grass (*Eriochloa polystachya*), suffered malnutrition effects during the six-month gestation period. The low normal protein content of the grass mixture, around 3.5 per cent, was probable the main factor involved. Malnutrition was unnoticed during the two-month pre-gestation period because, due to adequate and timely nitrogen fertilization the protein content of the grass mixture was raised to a higher level, around 11 per cent.

Nutrition studies involving mineral in animal blood require that the animal be fed with an adequate protein level during the whole experimental period.

SUMMARY

This paper reports spectrophotometric methods and transmittance-concentration curves for hemoglobin and iron in blood and phosphorus in blood serum and a photocolorimeter method and curve for calcium in blood serum.

Fifteen cross-bred virgin female goats were randomized in groups of five and fed according to three treatments: unlimed grass, limed grass, and limed grass plus manganese per os. Amounts of grass fed to each animal and their monthly weights were recorded for a one-month prefeeding period, a two month pre-gestation period, and a six-month gestation period. Blood samples were also drawn monthly from each animal for determination of hemoglobin, iron, hematocrits, red blood cells and white blood cells in blood, and calcium and phosphorus in blood serum.

The data are reported in nine tables. The important results are as follows:

1. There was no significant increase in the weight of the goats for the two-month pre-gestation period; however, there was a highly significant decrease in weight after the six-month gestation period.
2. There were significant differences for the pre-gestation period between the grass intake of the goats under the three treatments; the goats fed with unlimed grass ate less than those fed with limed grass. However, for the gestation period, the differences for the grass intake between the treatments was not significant.
3. The average intake of dry grass in pounds, and mineral in grams per day per group of five goats, covering the 243 days of the pre-gestation and gestation periods, are reported in table 5.
4. There were no significant differences in the pre-gestation between the mean red or white blood cells, the hematocrits, the hemoglobin and iron in the blood, and the calcium and phosphorus in the serum of the goats in the three treatments.
5. The goats were healthy and vigorous at the end of the pre-gestation period; but were skinny, bony and weak at the end of the gestation period (see photo).
6. The goats at the end of gestation, showed a reduction in red and white blood cells, in hematocrits, in hemoglobin, and in blood iron. However, no change was evidenced in the calcium and phosphorus of the blood serum.
7. Of the total of fifteen goats; ten aborted, and one died. Each of two goats delivered a weak kid, but produced no milk.
8. Stylbestrol, applied at the rate of 5 milligrams per os to each goat, to induce even ovulation, might have been the cause of upsetting the endocrine balance and affecting the health of the animal. A

marked increase was noticed in the calcium and phosphorus contents (table 7) of the blood serum after the stylbestrol applications.

9. Not all of the iron present in the blood is combined with hemoglobin (table 8).
10. The estimated protein intake per goat during the pre-gestation period was calculated to be about 65 grams per day (table 9), while that during the gestation period was about 40 grams per day. This protein deficit in the gestation period might have been an important factor causing malnutrition in the goats.

ACKNOWLEDGMENTS

This paper reports results obtained from a cooperative project between the Departments of Soils and Animal Husbandry that bears the title: "Effect of composition of soils and pastures on animals".

The writers wish to express their appreciation to the following members of the Animal Husbandry Department: Dr. Fernando E. Armstrong, Associate Veterinarian, for drawing the blood samples from the goats, and to Mr. V. Quiñones, former Assistant Chemist, for cooperation in the chemical analyses of the blood. Thanks are also expressed to Dr. C. Muñiz, former Veterinarian for his help in the preliminary work.

Our appreciation is also expressed to Miss Gloria María Soto, former Junior Chemist of the Soils Department, for helping in the chemical methods and analyses of the blood and in the statistical interpretation of the results; and to Dr. B. G. Capó, Biometrician and Head of Agronomy and Horticulture Department, for advice in the lay-out of the experiment and in the statistical interpretation of the results.

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LABORATORY RECOMMENDATION OF LIME TO AN ACID SOIL CHECKS WITH EXPECTED pH CHANGES

ALFONSO RIERA

INTRODUCTION

The agricultural value of about one million acres of acid soils in the humid area of Puerto Rico may be improved with the application of lime. The textures of these soils vary from the sands to the clays. Their organic matter has been reported (1) to vary from 1.0 per cent in the sandy soils to 51.5 per cent in the mucks. The buffer capacity of these soils is variable. A laboratory method for determining the lime requirement, which will be applicable to field conditions, is, therefore, of paramount importance.

Dr. B. G. Capó, Head of the Department of Agronomy and Horticulture, worked as a Soil Chemist in the Department of Soils from 1936 to 1942. While he was working in pot studies with soil-sand mixtures, using Hegari sorghum as a plant index to determine the available major nutrients in the soils, he adopted the following lime-requirement method to bring the acid soils to a convenient pH value.

LABORATORY METHOD

The air-dried soil samples are ground to pass a 1 mm. sieve. Calcium carbonate c.p. Baker Analized, is used as the lime source. Five portions of 20 grams of soil are weighed and placed in each of five 250 ml. beakers. The amounts of calcium carbonate added respectively, to each beaker, are 20, 40, 60, 80 and 100 milligrams corresponding to 1, 2, 3, 4 and 5 tons of calcium carbonate per acre. One hundred and fifty cubic centimeters of distilled water are added to each beaker. The mixture is stirred for 3 hours in a Ross-Kershaw apparatus, described as #9235 of Arthur H. Thomas catalog. The pH values of the supernatant liquids are determined and plotted on coordinate paper against the tons of calcium carbonate. The amount of limestone necessary to bring the pH of the supernatant liquid to the desired pH value is estimated from the corresponding curve.

FIELD RESULTS

"Fajardo clay" is an acid soil type derived from ashy shale. This soil type is well distributed in the terraces of the Experiment Station farm. Soil samples, at six-inch depths were taken on June 1943 from each of nine plots of "Fajardo clay" for the lime requirement tests. The amount of limestone necessary to bring the soil of each plot up to pH 6.5 was cal-

culated from the corresponding pH-lime requirement curve as described above.

The required amount of commercial ground limestone was applied to each of these plots and "malojillo" (Para) grass was planted on them on July 1943. On October 1944, soil samples were taken again at each of these plots, for pH determinations with the results that appear on table 1.

TABLE 1

Values of pH before and after liming

PLOT NUMBER	pH VALUE BEFORE LIMING	CALCIUM CARBONATE TO RAISE UP TO pH 6.5	pH VALUE 15 MONTHS AFTER LIMING
		tons/acre	
1	4.4	10.0	6.2
4	4.4	10.0	6.3
5	4.1	8.0	6.4
8	4.6	10.0	6.6
9	4.7	10.0	6.7
12	4.9	10.0	6.6
13	5.5	8.0	6.9
18	4.2	12.0	5.2
20	4.6	10.0	6.1

The difference between the mean pH values does not differ statistically from the desired value 6.5.

SUMMARY

A laboratory method for lime requirement in soils is presented. Lime was applied to the acid soil of nine plots of a field experiment at the rate found by this method. The pH changes fifteen months later did not differ statistically from the ones expected.

RESUMEN

Se expone aqui un método de laboratorio relacionado con la cal que necesitan los terrenos. Se aplicó cal a los terrenos ácidos de nueve parcelas que constituyeron el campo de un experimento, en la proporción determinada por dicho método. Los cambios pH, quince meses después, no se diferenciaron estadisticamente, de aquellos que se habían esperado.

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LACK OF RESPONSE OF SUGARCANE TO APPLICATIONS OF PHOSPHORUS IN PUERTO RICO

J. A. BONNET, B. G. CAPÓ AND A. RIERA

INTRODUCTION

In the last decade, 1934–1944, sugarcane, the most important economic crop of Puerto Rico, has occupied an average of 303,678 acres. The peak of total production was reached with the 1941–1942 crop which amounted to 10,010,132 tons of cane and yielded 1,147,589 tons of sugar. The Association of Sugar Producers of Puerto Rico reports that in 1941, from January to December, 141,000 tons of fertilizer raw materials were imported—80,000 tons ammonium sulphate, 36,000 tons superphosphate and 25,000 tons potash salts—from which about 80 per cent or 112,800 tons were used for sugarcane. The normal application for fall and spring plantings of sugarcane in Puerto Rico is six bags of 200 pounds each, per acre; and for ratoons, 4 bags per acre. Except for certain sections of the arid region of the South coast of the Island where ammonium sulphate is applied only, a complete fertilizer is used as a general practice. From July 1941 to June 1942, both inclusive, 92,975 tons of complete fertilizers (5) were applied to sugarcane in Puerto Rico. The available phosphoric acid in those fertilizers varied between four and ten per cent and added up to 5,658 tons P_2O_5. At the estimated price of $28.00 per ton of superphosphate containing 20 per cent available phosphoric acid, the consumption of phosphate fertilizer for the 1941–42 crop amounted to $792,120. The investment in phosphorus for sugarcane for the last 24 years (1920–1944) is estimated to be around ten million dollars.

The official fertilizer formulae for sugarcane approved by the War Production Board for manufacture in 1944–45, on the basis of NH_3,P_2O_5 and K_2O, are: 10–6–9, 12–4–9, 14–6–5, 14–6–8, 14–3–8, 14–0–7, 14–0–11. The demand for the formulae containing no phosphorus, however, has been practically negligible.

It is of economic importance, therefore, to determine if the continuous addition of phosphorus to the fertilizer is necessary for the sugarcane crop. It is also of importance to know if the placement of the fertilizer has any effect upon the response of the cane plant to applications of phosphorus.

EXPERIMENTAL WORK

A number of field experiments has been conducted in the past few years in which the need of phosphorus applications to maintain or increase

sugar yields has been under study. In these experiments, phosphoric acid fertilizers have been tried in different amounts, the rate of the phosphoric acid applications varying from zero to a maximum of four hundred P_2O_5 per acre. The actual rates of application as well as the mean cane yields obtained in these experiments are presented in tables 1 and 2.

The experiments were performed with several sugarcane varieties and they were established in the following 14 soil types (4) representing 84,224 acres of the most important sugarcane producing soils: "Toa silty clay loam", "Toa silty clay", "Toa clay", "Coloso silt loam", "Coloso silty clay loam", "Coloso silty clay", "Aguirre clay", "Vayas clay", "Vega Baja silty clay", "Mercedita clay", "Mabí clay", "Moca loam", "Vega Alta clay loam" and "Cataño sandy loam". The description of the soil series to which these soil types belong is as follows:

Toa. Series of the well-drained soils of the river flood plains in the humid area, derived from materials washed from the limestone and tuffaceous hills. They are neutral or slightly acid in reaction and are high in bases and plant nutrients. They are friable, brown soils from the surface to a depth of below four feet. The productivity rating of the loam to clay types is 1, i.e., they are rated among the best soils.

Coloso. Series of the poorly drained soils of the river flood plains in the humid area, derived from neutral, fine textured materials of volcanic rocks and limestone. They are poorly drained associates of the "Toa" series. They are deep, stone free, highly fertile, neutral, and plastic. Most areas have a heavy texture, a high water table, a dark surface soil, and a mottled-gray, bluish-gray, and rust-brown subsoil. The productivity of the heavy types is rated between 1 and 2.

Aguirre. Series of the poorly drained soils of the river flood plains in the arid area, that occupy areas that are transitional in character between the soils of the well drained river flood plains or alluvial fans, and the poorly drained soils of the coastal lowlands. In a cultivated field, "Aguirre clay" has a 10 or 12 inch very dark, grayish-brown and gray plastic sticky clay that continues to a depth ranging from 30 to 36 inches. The upper part of the substratum is a mottled-gray, rust-brown, and yellowish-brown, medium plastic, wet silty clay, that in places contains some medium-sized gravel. At a depth ranging from 5 to 6 feet is the substratum of bluish-gray, plastic, sticky wet clay. This layer continues to considerable depths and has characteristics of estuarine deposits. Nearly all of the layers in the profile contain free lime; many areas contain salts, chiefly sodium carbonate, that limit crop production. Areas that contain less than 0.2 per cent of salts within the first four feet are used under irrigation for the production of sugarcane. It has a productivity rating of 2. The

TABLE 1

Percentage increases in cane yields obtained when phosphoric acid applications were made

CROP NO.	SOIL TYPE AND LOCATION	CANE VARIETY	KIND OF CROP AND YEAR	FERTILIZERS APPLIED PER ACRE			CANE YIELDS PER ACRE	INCREASE IN YIELD
				NH_3	P_2O_5	K_2O		
				cwts.	*cwts.*	*cwts.*	*tons*	*per cent*
1	Coloso silty clay, Toa Baja	BH-10(12)	Plant Cane 1937–1939	4 4	0 4	4 4	69.3 70.2	1.3
2	" "	BH-10(12)	First Ratoon 1939–40	4 4	0 4	4 4	50.7 46.7	−7.9
3	" "	BH-10(12)	Second Ratoon 1940–41	4 4	0 4	4 4	37.6 40.8	8.5
			Average of 3 crops	4 4	0 4	4 4	52.5 52.6	0.0
4	Coloso silt loam Toa Baja	BH-10(12)	Plant Cane 1938–40	4 4	0 4	4 4	68.4 71.2	4.1
5	" "	BH-10(12)	First Ratoon 1940–41	4 4	0 4	4 4	49.8 46.9	−5.8
			Average of 2 crops	4 4	0 4	4 4	59.1 59.1	0.0
6	" "	POJ-2878	Plant Cane 1938–40	4 4	0 4	4 4	65.3 65.0	−0.5
7	" "	POJ-2878	First Ratoon 1940–41	4 4	0 4	4 4	62.4 60.3	−3.4
			Average of 2 crops	4 4	0 4	4 4	63.9 62.7	−1.9
8	" "	M-28	Plant Cane 1938–40	4 4	0 4	4 4	66.7 67.1	0.6
9	" "	M-28	First Ratoon 1940–41	4 4	0 4	4 4	45.5 41.6	−8.6
			Average of 2 crops	4 4	0 4	4 4	56.1 54.4	−3.0
10	" "	M-275	Plant Cane 1938–40	4 4	0 4	4 4	67.2 68.1	1.3

TABLE 1—*Continued*

CROP NO.	SOIL TYPE AND LOCATION	CANE VARIETY	KIND OF CROP AND YEAR	FERTILIZERS APPLIED PER ACRE NH₃	P₂O₅	K₂O	CANE YIELDS PER ACRE	INCREASE IN YIELD
				cwts.	*cwts.*	*cwts.*	*tons*	*per cent*
11	Coloso silt loam Toa Baja	M-275	First Ratoon 1940–41	4 4	0 4	4 4	58.4 60.9	4.3
			Average of 2 crops	4 4	0 4	4 4	62.8 64.5	2.7
12	Aguirre clay, Salinas	BH-10(12)	Plant Cane 1940–42	4.5 4.5	0 3	4 4	45.1 41.5	−8.0
13	" "	POJ-2878	Plant Cane 1940–42	4.5 4.5	0 3	4 4	42.8 45.0	5.1
14	Mabi clay, Juncos	POJ-2878	Plant Cane 1940–42	4.5 4.5	0 3	4 4	75.4 79.0	4.8
15	Mercedita clay, Ponce	BH-10(12)	Plant Cane 1940–42	4.5 4.5	0 3	4 4	97.0 95.2	−1.9
16	" "	POJ-2878	Plant Cane 1940–42	4.5 4.5	0 3	4 4	108.8 102.1	−6.2
17	Toa silty clay, Manatí	M-275	Plant Cane 1941–43	2.325 2.325	0 1.55	2.325 2.325	94.9 105.0	10.6
18	Toa silty clay loam, Manatí	BH-10(12)	Plant Cane 1942–43	3 3	0 2	3 3	74.2 73.7	−0.7
19	Coloso silt loam, Fajardo	BH-10(12)	Plant Cane 1937–39	4 4	0 4	4 4	89.8 82.0	−8.7
20	" "	BH-10(12)	First Ratoon 1939–40	4 4	0 4	4 4	48.4 53.9	11.4
			Average of 2 crops	4 4	0 4	4 4	69.1 68.0	−1.6
21	Moca loam, Toa Baja	POJ-2878	Plant Cane 1939–40	3 3	0 3	3 3	40.4 43.5	7.7
22	Coloso silty clay loam, Naguabo	BH-10(12)	First Ratoon 1937–39	3 3	0 3	3 3	81.9 79.9	−2.4
23	Cataño sandy loam, Añasco	POJ-2878	Plant Cane 1937–38	0.9 0.0	0 0.9	0.9 0.9	47.4 49.9	5.3
24	Toa clay, Hormigueros	POJ-2878	Plant Cane 1937–38	0.9 0.9	0 0.9	0.9 0.9	36.9 37.4	1.4

land is difficult to plow and cultivate because when wet it is plastic and sticky, and when dry it is hard and cloddy.

Vayas. Series that occupy the more poorly drained level areas along

TABLE 2

Percentage increases in cane yields obtained with increases in phosphoric acid applications above the minimum 0.20 cwt. P_2O_5 per acre applications

TREATMENTS			POJ-2878, VEGA ALTA CLAY LOAM, RÍO PIEDRAS, FIRST RATOON, 12 MONTHS. 1943-44		BH-10(12), VAYAS CLAY, SANTA RITA			
					First ratoon, 12 months. 1942-43		New planting of plant cane, 10 months. 1943-44	
NH_3	P_2O_5	K_2O	Yield	Per cent increase	Yield	Increase	Yield	Increase
cwt./A.	*cwt./A.*	*cwt./A.*	*tons/A.*		*tons/A.*	%	*tons/A.*	%
1.25	0.20	0.90	39.9		33.8		24.4	
1.25	0.80	0.90	38.8	−2.8	30.0	−11.2	24.1	−1.2
1.25	0.20	1.80	37.0		30.5		22.5	
1.25	0.80	1.80	39.1	5.7	29.9	−2.0	23.3	3.6
1.25	0.20	2.70	39.6		27.0		25.5	
1.25	0.80	2.70	40.6	2.5	31.4	16.3	24.0	−5.9
2.00	0.20	0.90	36.9		29.9		21.0	
2.00	0.80	0.90	37.0	0.3	32.5	8.7	25.3	20.5
2.00	0.20	1.80	38.8		29.3		21.0	
2.00	0.80	1.80	39.3	1.3	32.8	11.9	26.9	28.1
2.00	0.20	2.70	38.0		30.1		23.1	
2.00	0.80	2.70	37.9	−0.3	29.1	−3.3	26.9	16.5
2.75	0.20	0.90	37.9		32.3		24.4	
2.75	0.80	0.90	38.6	1.8	30.6	−5.3	22.1	−9.4
2.75	0.20	1.80	41.3		34.3		26.6	
2.75	0.80	1.80	37.1	−10.2	27.5	−19.8	20.5	−22.9
2.75	0.20	2.70	36.1		32.8		26.8	
2.75	0.80	2.70	37.9	5.0	29.9	−8.8	23.6	−11.9
3.50	0.20	0.90	37.9		29.9		23.5	
3.50	0.80	0.90	34.6	−8.7	33.3	11.4	28.1	19.6
3.50	0.20	1.80	40.0		29.5		26.3	
3.50	0.80	1.80	35.5	−11.3	31.4	6.4	24.4	−7.2
3.50	0.20	2.70	37.6		32.9		26.5	
3.50	0.80	2.70	38.5	2.4	30.3	−7.9	27.5	3.8
Average with 0.20 cwt. P_2O_5 p/A.			38.4		31.0		24.3	
Average with 0.80 cwt. P_2O_5 p/A.			37.9	−1.3	30.7	−1.0	24.7	1.6

the river flood plains in the semiarid south coast section. "Vayas clay" has a brown or dark-brown clay in the surface and a mottled-gray or rust-brown and yellowish-brown layer beginning at a depth of about 30 inches and continuing to considerable depths. The average upper limit of the

water table is about 30 inches. Nonalkali areas have a productivity rating of 1. When wet it is plastic, and when it dries large cracks appear on the surface.

Vega Baja. Series of the poorly drained soils of the river flood plains in the humid region. They occupy bordering or intergrade areas between the alluvial soils and the coastal plain soils. They are slightly above normal overflow, but during exceptionally high water are flooded. The surface soil of the silty-clay type, to a depth of eight or ten inches, is acid, friable and granular. It has a light-brown or grayish-brown color. This layer changes abruptly to a plastic, medium compact, mottled, yellowish-brown, gray and red silty clay or clay subsoil, which continues to considerable depth, and becomes more definitely mottled and more acid with depth. Its productivity is rated between 2 and 3.

Mercedita. Series of the inner plain soils in the arid region. The 12 inch surface soils of Mercedita clay consist of brown or dark-grayish-brown, granular calcareous clay, which is very plastic and waxy when wet. The subsoil is yellowish-brown or light olive-brown, medium compact, plastic calcareous clay, ranging from 10 to 15 inches in thickness. Below this layer is a very limy, friable, light-yellow silty material and soft limestone, which continues below a depth of 5 feet. Some areas contain harmful quantities of salts. Many areas are affected with lime chlorosis Its productivity is rated at 2.

Mabí. Series of the inner plain soils in the humid region. "Mabí clay" occurs on long low gentle slopes, in close association with the "Múcara" and related brown, shallow soils of the uplands. It is derived from tuffaceous material, partly residual, and in part colluvial and alluvial. It has a grayish-brown, neutral, plastic heavy, clay surface soil, about eight or ten inches thick, which has good tilth when properly plowed and cultivated. The subsoil is a yellowish-brown, plastic sticky, neutral, heavy clay, streaked with rust-brown and gray material. This layer gradually changes, at a depth ranging from 30 to 40 inches, to friable brown and yellowish-brown silty clay loam that crumbles readily between the fingers. The material grades into desintegrated tuffaceous rock material at a depth ranging from four to 12 feet. Small fine white specks of the rock material occur in all layers. Its productivity is rated at 3.

Moca. Series of the inner plain soils in the humid area. "Moca loam" occurs on low sloping areas near the limestone hills. It has eight or ten-inch, acid, brown or dark-brown friable loam, which abruptly changes to heavy plastic, sticky, acid silty clay, or clay that is mottled red, gray, and brown. This layer continues downward for many feet. All layers contain a few rounded pieces of gravel or small rocks. Its productivity is rated at 6.

Vega Alta. Series of the friable soils of the coastal plains in the humid

region. "Vega Alta clay loam" has a friable, brown or light-brownish-gray, acid surface, about eight inches thick, underlain by a reddish-brown, heavy, slightly plastic clay layer about 10 or 12 inches thick. This layer rests on more compact, mottled, brown, red, and gray clay, which continues to great depths before limestone is reached. Its productivity is rated at 5.

Cataño. Series belonging to the soils of the coastal lowlands in the humid region. It occurs as a narrow strip paralleling the sea, a short distance inland. It has a 10 or 12 inch surface soil of grayish-brown or dark-grayish-brown, loose noncoherent loamy sand, alkaline in reaction. This layer is underlain by a lighter colored and lighter textured calcareous subsoil about two feet thick. The substratum, to a depth ranging from 10 to 15 feet, is loose, friable sand. Its productivity is rated at 6.

The mean contents of phosphoric acid available in 1% citric acid, for various samples of soil types corresponding to the above soil series have been reported elsewhere (2.3) and are as follows:

SOIL SERIES	SAMPLES ANALYZED	AVAILABLE P_2O_5
Toa	21	.012
Coloso	18	.015
Aguirre	1	.041
Vayas	1	.072
Vega Baja	4	.013
Mercedita	1	.001
Mabi	11	.005
Moca	3	.003
Vega Alta	5	.008
Cataño	8	.017

The mean contents of total phosphoric acid of 7 samples of the Toa series and of 6 samples of the Coloso series were found (2) to be .113 and .154 per cent, respectively.

In general, the soil series of the arid region of Puerto Rico (3) contain about twice as much available phosphoric acid, soluble in 1% citric acid, than the soil series of the humid region. The mean difference is significant at the 1% point. The figures are as follows:

PER CENT AVAILABLE P_2O_5 IN SOIL SERIES OF		
Humid Area	Arid Area	Mean Difference
.0079 ± .0007	.0173 ± .0030	.0094 ± .002

Highly significant.

EXPERIMENTAL RESULTS

Table 1 shows the yields of cane, in tons per acre, obtained in twenty-four crops of various sugarcane field experiments, both without and with a heavy application of phosphoric acid. Heavy applications of nitrogen and potash were added in all cases to insure the maximum possible responses from the phosphoric acid applications.

The first eighteen crops are from experiments performed in cooperation between the Soils and Agronomy Departments of the Agricultural Experiment Station of the University of Puerto Rico. Crops number 19 and 20 belong to an experiment carried out by Mr. Juan E. Veve, while at the Central Fajardo Experiment Station; crop no. 21 is from an experiment performed by Mr. Fernando Chardón at Central Constancia; crop no. 22 is from an experiment carried out by Mr. H. A. Nadler, Jr. of Eastern Sugar Associates; and crops nos. 23 and 24 were reported (1) by the Puerto Rico (Mayaguez) Agricultural Experiment Station.

Table 2 presents data relative to three crops of two long-time sugarcane field tests which are being performed by the Soils Department of the Agricultural Experiment Station of the University of Puerto Rico at Río Piedras and Ensenada.

The mean cane yield differences obtained with the various phosphoric acid applications in each of the experiments described in tables 1 and 2 were not statistically significant. This indicates that the sugarcane yields were not affected by the phosphoric acid applications, even in the case of crop number 3, which was the third crop in succession in which a heavy application of phosphoric acid was tested against no addition of this substance. That is, the phosphoric acid which this soil contained at the beginning of this test sufficed at least for maximum cane yield production of a plant cane and two ratoon crops. Similar statements may be made for the two consecutive crops, number 4 to 11 and 19 to 20.

The lack of response of the sugarcane crop to the phosphoric acid applications in these experiments may have been due to one of two reasons:

1. The soils were in condition to supply the crops with enough phosphoric acid as to render unnecessary and superfluous any further applications of the substance.
2. The phosphoric acid, applied as superphosphate on top of the soil in some of the experiments described in table 1, was not able to penetrate to the root zone and did not exert its possible beneficial action on the crop.

If the first of the two reasons advanced above is applicable, then it must be admitted that sugarcane behaves differently from other crops such as native red beans, eggplant, corn, cucumbers, and sudan grass, all of which have responded markedly to phosphoric acid applications in several ex-

periments performed on soil types similar to those in which the sugarcane has not responded to those applications. The long-time field experiments established at Río Piedras and Ensenada will be continued for a long number of years to determine how long will the minimum 20 pounds P_2O_5 per acre under test be able to maintain crop yields at the same levels as those obtained with the 80 pounds P_2O_5 per acre applications.

TABLE 3

Effect on the sugar cane yield of the method of applying the fertilizer

NUMBER	TREATMENT: Method of applying the fertilizer, (300 lbs. NH_3, 100 lbs. P_2O_5 and 200 lbs. K_2O, per acre per crop)	F-1017 ON "VEGA BAJA SILTY CLAY," RÍO PIEDRAS. AUGUST 1940 TO MAY 1944: Plant cane	First ratoon	Second Ratoon	Total for 3 crops
		Tons cane per acre			
1	Phosphate for plant cane and two ratoons mixed with the soil in the furrow before planting; ammonia and potash applied to each crop on two 3-inch deep furrows at the sides of each row one month after last replanting	66.2	50.7	31.7	148.6
2	Phosphate for plant cane and two ratoons mixed with the soil in the furrow before planting, ammonia and potash on top soil for each crop, one month after last replanting	67.0	53.2	30.5	150.7
3	Complete fertilizer applied to each crop on 3-inch deep furrows at the sides of each row, one month after last replanting	69.6	53.0	31.5	154.1
4	Check—Complete fertilizer applied to each crop, on top of the soil, one month after last replanting	68.4	53.8	34.0	156.2

To test the possibility of the second of the two reasons presented above, a fertilizer placement experiment was performed on a "Vega Baja silty clay" field very near to fields where heavy responses to the phosphoric acid applications had been observed with sudan grass and red beans.

In this experiment, different ways of applying the phosphoric acid were tested. The rates of application, yields obtained and other details are presented in table 3.

The statistical analysis of the results obtained in this experiment indicated that none of the differences between the mean yields corresponding to the various ways of applying the fertilizer was significant. In this case, therefore, the second reason is not applicable.

In view of the above results, it may be concluded for the time being that maximum sugar cane crops may be raised in the coastal plains of Puerto Rico without the application of any phosphoric acid for at least one crop cycle, that is, a plant cane and 2 ratoon crops. The results of the long-time tests under way at present will indicate in the near future whether this period may be lengthened and, if so, by how much.

The above results do not corroborate the statement which appeared in page 84 of the 1927–28 annual report of the Insular Experiment Station of Puerto Rico to the effect that an application of "phosphoric acid in excess of sixty pounds per "cuerda" (0.9712 acre) lowers the gain in yields of sugarcane". As the above data indicate, phosphoric acid applications, up to a maximum limit of four hundred pounds P_2O_5 per acre, have not affected, either for better or worse, the cane yields in the lowlands of Puerto Rico in experiments lasting a maximum of three and a half years. It is believed that the harmful effect of the heavy applications of phosphoric acid, was rather due to the fact that in the treatments involving such phosphoric acid applications the nitrogen level was lower than where smaller applications of phosphoric acid were made.

SUMMARY

1. The yearly investment in phosphoric acid as a fertilizer for sugarcane in Puerto Rico is about $800,000.

2. Phosphoric acid applications have not exerted any effect, either beneficial or detrimental, on the cane yields of several successive sugarcane crops grown on the coastal plains of Puerto Rico.

3. Sugarcane may be raised for several years in the coastal plains of Puerto Rico without any phosphoric acid applications and with no appreciable reduction in sugarcane yields.

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THE EFFECT OF CERTAIN MICRONUTRIENT ELEMENTS ON THE GROWTH AND YIELD OF PINEAPPLE PLANTS

by **Francisco J. Ramírez-Silva**

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I—INTRODUCTION *

The pineapple was, almost certainly, native of Brazil (5), and very probably the Caribs or Arawaks took some to Puerto Rico before the sixteenth century.

The pineapple (66) is related to the bromeliads and air plants, and it can absorb nutrient constituents through its leaf axils and long-barbed and barbless bayonetlike leaves that protrude from numerous whorls on the main stalk. The so-called pineapple fruit is an aggregate of many individual fruits with their fibrous juice pulp surrounding the core. Pineapple plants are propagated under field conditions from three asexually produced vegetative organs, known respectively as suckers, slips, and crowns. (See figure 1). In some varieties each individual fruit has a number of seeds which can be used for propagation but the most common practice is to plant slips or suckers. The slip resembles a miniature plant and is produced near the base of the fruit. The suckers resemble the slips, but are larger. The crown slip is produced at the top of the fruit: it is rarely used for propagation.

After one crop of pineapples is harvested a second crop, or ratoon, is produced from a new plant resembling a sucker which is formed at the base of the main stalk in contact with the soil.

Pineapple plants respond to good soil that must be well managed, not too alkaline or wet, and well aerated. The acreage in pineapples in Puerto Rico is relatively low compared to that in other crops. The total value of the export crop is high, although very low if compared with sugar cane. Practically all fresh and canned pineapples exported go to the United States where they are considered of good quality and get the highest prices.

The pineapple growers of Puerto Rico claim that the yields from native slips show a yearly lowering in production, as if they were degenerating or as a result of a "rundown" of the stock. Slips imported from Cuba when first planted in Puerto Rican soil, show considerably greater vigor than native slips. They give higher yields than the native stock brought originally from Cuba. It has been observed also that Cuban stock will show signs of decreased vigor and yield after a few years of propagation. Since pineapples are,

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FIGURE 1.—A pineapple plant showing the position of slips, suckers and crown.

as explained above, propagated under field conditions from asexually produced vegetative organs, the degeneration is probably not on a genetic basis. On the other hand, no degenerative disease such as mosaic has ever been found. Hence, there is evidence of the possibility of a nutritional disturbance, perhaps in the micronutrient elements, that may produce vegetative organs with low reserve nutritional elements. These, on being planted in a soil causing such disturbance, may bring about the above-mentioned apparent degeneration of the stock.

This nutritional derangement may have been produced by changes in the soil as a result of faulty cultivation methods, fertilizer practice, constituents of the parent material of the soil, poor crop rotation and conservation. It is claimed, however, that slips planted on virgin soil or on soils not used before for pineapple planting, do not show this degeneration taking place so rapidly as on soils previously used for several years under continuous pineapple production.

Pineapple chlorosis has also been known in Puerto Rico from early times, as shown in works done by Gile (25) since 1911, and by Henricksen (31, 32) in 1925. Similarly, pineapple chlorosis was also known in Hawaii as shown in the experiments of Kelly (50, 51, 52, 53) from 1909 to 1914, also of Wilcox and Kelly (85) in 1912, and of Johnson (45, 46, 47, 48, 49) in 1916-1924.

This yellowing is a source of considerable loss. Spraying of the chlorotic pineapple plants with iron sulfate solution has been practiced in Puerto Rico and in Hawaii, this being an adequate remedy for this malady.

These problems were brought to the attention of Schapelle (67, 68, 69, 70, 71) in 1939, at the Agricultural Experiment Station of the University of Puerto Rico. He set up experiments in order to examine the effect of different nutrient elements under different treatments in the field and under different concentrations of macro and micronutrient elements in solution cultures. His investigations on the nutritional aspect of these pineapple problems in Puerto Rico were followed by the experiments of Hopkins, Pagán, and Ramírez-Silva (40). The experiments presented in this dissertation are part of this series of greenhouse and field investigations on the above-mentioned pineapple problems. The effect of the micronutrient elements: iron, manganese, aluminum, boron, copper and zinc, on pineapple growth and production was examined by means of different treatments in solution cultures.

In accordance with Hoagland (34) who considers the terms "minor elements," "rare elements," and "trace elements" as inappropriate, we use the term he suggested, that is, "micronutrient" elements. Among these are iron, manganese, aluminum, boron, zinc, copper, etc., called micronutrient elements because of the minute concentrations in which they are found in plants. Very minute quantities of them are required to perform their essential functions in plant nutrition. Also, small amounts of them are enough for plants to restore themselves from the specific abnormalities and impaired physiological functions caused by their deficiency in the nutrient medium.

In contrast with these "micronutrient" elements there is a group of elements once called "essential" elements and now usually called "major" elements in plant nutrition. Among them are: nitrogen, potassium, phosphorus, calcium and magnesium. As they are found in greater quantities, they will be referred to as "macronutrient elements." In this sense, the idea of either major or minor, or of essentiality, will not be erroneously conveyed. It may be the case that the so-called "minor elements" be of "major" importance in some cases of plant nutrition. No element is "major" or "minor"; they may be either macronutrient or micronutrient, according to their concentration in plants.

The artificial culture method has been found to be a valuable tool in plant nutrition research. This method has been termed "hydroponic," "water culture," "sand-culture," "gravel-culture," "solution-culture," etc. The term "water-culture" is widely used. but it is not as accurate as the term "solution-culture," since it is a solution of nutrient substances that is used in this artificial method. Of course, when sand or gravel is used in the culture media, the corresponding term of sand or gravel culture is appropriate.

II—REVIEW OF LITERATURE

A. *The growth of plants in artificial media in relation to the study of plant nutrition*

In order to study the role played by nutrient elements in the plant, and in an attempt to separate this from the problem of the availability of the nutrient elements in the soil, that is, from the soil-solution problem, the artificial culture method has come to be a valuable tool in this field of research.

The method of growing plants in nutrient solutions has been used as the best known means of controlling the concentrations, pH,

and proportions of nutrients fed to plants in experimental treatments. The convenience of this method, as well as the objections to it, depend upon the specific problem under experimentation.

Since the earliest recorded experiments with solution cultures by Woodward (61) in 1699, and later on by procedures developed by Sachs, Knopp, and Nobbe, from 1859 to 1865, the modifications introduced by means of different formulas and techniques have made this medium of growth for plants very useful for the purposes of fundamental experimentation and preliminary trials for field work and research.

Hoagland (34), on his discussion of the topic of growth of plants in artificial media in relation to plant nutrition, taking in consideration the dominating phases of this subject, appraises the far-reaching scientific significance of this method and its great service in understanding the nature of the soil-plant system.

According to Miller (61), nutrient solution formulas have been proposed by Tollens in 1882, Schimper in 1890, Pfeffer in 1900, Crone in 1902, Tottingham in 1911, Shive in 1915 (73), Hoagland in 1920, and many others. The osmotic pressure of the solutions has been considered, also, the relationship between proportion of salts, the growth effect of light and temperature, the relative absorption of ions, and the functions of the elements essential to plant life. Miller (61) shows a list of useful formulas for nutrient solutions.

Shive's (73) three-salt solution of KH_2PO_4, $Ca(NO_3)_2$ and $MgSO_4$ has been the basis of much experimentation by him and others. They have considered the osmotic pressure best fitted to certain crops, the supply of essential elements, and the relation of the elements as found in soil extracts. The formulas derived from Shive's three-salt solution have been classified in series according to osmotic pressures and the molecular proportions of the dissolved components. They are designated by serial numbers when reference is made to them in experimental work.

For experimental purposes it has been recommended that renewal of solutions be made at least every month, and if possible continual removal, aeration by bubbling air, adequate temperatures, uniformity in light supply, and the use of pure chemicals and distilled water.

The works of Lowhwing (54) in 1932, of Clark and Shive (19) in 1932, and of Bryant (11) in 1934, show that nonaerated nutrient solutions tend toward a greater ratio of roots to tops. This suggests the idea of growing plants for a certain period of time, in the beginning without aeration, later on aeration is applied as required for normal crop production.

The preparation of separate solutions to prevent precipitation of concentrated salts upon being mixed was recommended by Tottingham (81) in 1914.

B. *Researches on nutrition of pineapple plants as related to micronutrient elements*

During the last two decades mineral deficiencies in plants have been the subject of much experimentation in the field of plant nutrition. Nevertheless, the question of toxicity due to excess of certain nutrient elements has not been emphasized to a great extent from the standpoint of practical plant culture. The balancing, additive, and antidoting effects between certain nutrient elements have been the subject of still less investigation. Examples of this toxicity are shown by manganese in pineapple plants, as reported from Hawaii by Kelly (50, 51, 52, 53) in 1908-1912, by Johnson (45, 46, 47, 48, 49) in 1916-1924, by Wilcox & Kelly (85) in 1912, and by McGeorge (58) in 1923.

In 1911-1916, Gile (25, 26) and Gile and Ageton (27) found a type of chlorosis of pineapples in Puerto Rican soils that contained large quantities of calcium carbonate and no excessive manganese. They called such chlorosis, lime-induced chlorosis. They noticed that spraying with solutions of iron salts resulted in the restoration of the green color. Johnson (45) in 1916, however, traced the pineapple chlorosis as due to manganese toxicity with a condition of low or no iron absorption, and found that spraying with iron sulphate solution counteracted the effect of high manganese present in the soil. On the other hand, Gile (25) found that this spraying of plants had to be repeated so often that it was not economically practicable.

As we are dealing with the general term "chlorosis", it must be explained here that it stands for a diseased or unhealthy condition of the leaves shown by the loss of the green coloring matter. This yellowing may be due to several factors such as lack of the nutriments producing or intervening, directly or indirectly, with the process of chlorophyll formation, to poor drainage or bacterial effects. After the leaves become strongly chlorotic necrosis ensues, showing extensive black areas.

Schapelle (67, 70, 71) in 1940, attempting to elucidate the problem of the apparent degeneration of pineapple stock and the increasing chlorosis of pineapple plants grown in Puerto Rican soils,

made studies on the effects of macro and micronutrient elements on the growth, yield, chlorosis, and quality of fruits of pineapple plants. He found that potassium was an important factor in the quality of the fruits, that plants responded better to ammonia than to nitrate nitrogen. He noticed that chlorosis was a cause for lower yields. He found profitable the use of frequent spraying with ferrous sulfate solutions. In experiments with pineapples grown in nutrient solutions he used with success a modified form of the solution used by Sideris, Krauss, and Young (74). He had demonstrations of best growth under the conditions of the experiment at a pH around 4.5, that manganese and zinc tended to produce chlorosis, that aluminum and boron tended to counteract the effects of manganese and zinc, and that copper, added at the concentration of 2 p.p.m. controlled a root fungus that caused stunting of the pineapple plants.

After this work of Schapelle (67, 70, 71), Hopkins and co-workers (40) in 1944 started their work along this line of research not only using the pineapple plants but also beans and tomatoes. They found: (*a*) high amounts of water-soluble manganese in soils from pineapple growing areas, (*b*) observed the chlorosis of pineapples grown in those soils, and that beans would not grow on them on account of severe chlorosis, (*c*) that in spite of the correction of chlorosis in pineapples by spraying with ferrous sulphate, certain abnormalities occurred, such as reduction in size of the plant and development of more red pigments than normally, (*d*) slips imported from Cuba, of the variety "Red Spanish," produced larger and greener plants than slips from the same variety from Puerto Rican plants; but after being planted for two generations in Puerto Rico, plants originally from Cuban slips reverted to the inferior type, (*e*) many fruits produced in these soils were affected with "short top," that is, a very short crown in the fruit which appears to be brought about by high soluble manganese under high intensity of light. The pineapple soils have pH as low as 3.8 which brings manganese into solution. Tomato plants used for preliminary experiments showed high correlation of maximum growth with the wider ratio of Fe to Mn. Tomato plants show a great sensitivity to manganese, requiring a large ratio of Fe to Mn for normal growth, flowering and production. It was noticed that the reserve of iron in seeds or propagating organs supplied the plant during a certain period of the early growth with the iron necessary to antidote the manganese in the nutrient solution, in either soil or solution culture.

C. *Researches on plant nutrition as related to micronutrient elements used in these experiments*

The micronutrient elements used in this experiment: iron, manganese, copper, zinc, aluminum and boron, have been the subject of an immense amount of research. To review and make a thorough study of all this literature would be outside the scope of this dissertation, but a chronological review of investigations having a bearing on this experiment is necessary. In the following pages such a review is made, taking in consideration that some references have already been mentioned in previous sections.

1. *Iron*

Iron is essential for the growth of plants. In them it is almost universally present in small quantities. Molisch in 1892, as quoted by Miller (61), found that most iron in plants is in a combined, insoluble form. Iron apparently occurs in plants in two forms, namely, the "active and inactive", sometimes also called "available and non-available".

Although plants deprived of iron show marked chlorosis, it has been definitely proved by Willstatter and Stoll in 1913 that iron does not enter into the composition of chlorophyll. Gile and Carrero (28, 29, 30), studied in 1914–1916 the iron requirements of rice, pineapples, and other crops. They noticed that iron, after being transported to the leaves, is immobile, and that colloidal iron is not absorbed by plants. Warburg (83) proposed in 1925 the theory that iron is the oxygen-carrying component of the respiration ferment. Hopkins (36) 1930, believed in the important role played by iron in the cellular processes involving biological oxidation.

According to Miller (61), the researches made by Oddo and Pollaci in 1920, Deuber in 1926, and Pollaci in 1935 show a possible explanation of this role of iron as a catalytic agent in chlorophyll formation, catalyzing the formation of the pyrrole nucleus which is the center of the chlorophyll complex.

Gile and Carrero (30) in 1920, and Willis and Carrero (87) in 1923, agreed in considering that lime–induced chlorosis is due to a depression in the available iron. Rippeal (65) observed in 1923, that chlorosis produced by manganese in the form of soluble salts in solution cultures, was overcome by increasing the supply of iron. He concluded that manganese interfered with the iron within the plant and not with its absorption.

Gericke (24) noticed in 1923 that iron-deficiency symptoms were more acute in plants under lights of high intensity than in lights

of low intensity. This should be examined according to the results of experiments made by Hopkins, Pagán and Ramírez-Silva (40) in 1944. They noticed phototropic effects of manganese in the absence or low level of iron. It is possible that Gericke was taking for iron deficiency what may be called manganese toxicity.

Burk, et al (16), made a report on the experiments made on metallic humates up to the year 1931 and, with reference to iron humate, they pointed out important facts that show the advantages in using humic acid for furnishing iron in a permanently soluble form in soils and in artificial culture media. The humic acid itself does not act by increasing directly the availability of constituents added to or present in the culture medium; or by activating toxic metabolic products; or by affecting surface tension, viscosity, and potential differences between culture medium and organism, or the oxidation potential of the media; but provides iron for growth and nutrition in a more highly available form.

Horner, Burk and Hoover (41) explained in 1934 a method of preparing humate metals from the salts of the corresponding metal and humic acid made from sucrose. This method is simple and provides a soluble form of iron at a very wide range of pH values. It is of great utility in solution cultures where available iron is required for treatments at different pH values, and also when the culture solution is subjected to variations in pH. These humates are stable in alkaline, neutral and moderately acid media, and are not precipitated by phosphates.

The role of iron in plant metabolism should be related to enzymes called iron enzymes, namely, catalase, peroxide, citochromes, indophenol oxidase, and others.

2. *Manganese*

Manganese is widely distributed in nature. It is an essential element for plant growth and functions in the synthesis of chlorophyll and carbon assimilation. According to McHargue (60), previous to 1774 the compounds of this element were confused with those of iron. In that year Scheele discovered that the metal found in pyrolusite, manganese, is altogether different from iron. Gauhn isolated the metal shortly afterwards. Thus Scheele started the work to investigate the functions of manganese in plant economy and its occurrence in soils. Ninety years later Sachs was able to prove that plants assimilate manganese and that it cannot replace the functions of iron in plant growth. By 1894 Bertrand had already determined the chemical composition of the sap of the lac tree and found that

its ash contained 2.5 per cent of manganese. The importance of manganese, in spite of the small content of it in plants, was by that time already recognized.

The works of McHargue, in 1914, showed that manganese and iron play an important role in chlorophyll formation and that this element may be toxic to plants at certain levels of concentration in the nutrient solution.

Sachs in 1865 noticed yellowing and etiolation of leaves in an attempt to substitute manganese for iron. Field observations on pineapples grown in manganiferous soils show that the interior of the fruits have a whitish appearance and usually contain excess acidity. Lime application makes manganese toxicity worse.

In 1908 Fukutome (22), from Tokyo, in his experiments on flax, noticed beneficial action when iron sulfate was added to manganese treatments. This is sometimes termed antagonism, counteracting effect, or antidoting action. Masoni (55) also observed in 1911, in his experiments with corn and lupines, the beneficial counteracting effect of iron on the detrimental action of manganese.

Stocklasa, J., (79) noticed in 1911 that aluminum and manganese have an additive beneficial effect on the growth of several plants.

Wilcox and Kelly (85) in 1912, in their experiments with pineapples, grown in Hawaii, made a thorough study of the physiology and chemistry of pineapples as affected by manganese toxicity. They do not mention the antidoting action of iron. They observed the mechanism of chlorosis, and the bad effects on roots due to excessive soluble manganese in the nutrient solution.

Kelley (53) in 1914 indicated that manganese may have an effect upon soil so as to bring about the mobilization of calcium and magnesium, and that it may stimulate the oxidation going on within the plant and in the soil.

The antidoting action of other cations as Ca, K, Na, and Mg on Mn was observed by McCool (56) in 1913. It may be that the beneficial effect of manganese is only due to the association or counteraction of other cations. He noticed that the deleterious effect of manganese varied inversely with the intensity of light.

Funchess (23) noticed in 1918 that nitrates and nitric acid increased the toxic concentrations of manganese.

Hopkins (36, 37) in 1930 reported the increase of growth of chlorella six hundredfold by addition of manganese to the nutrient solution, and he suggested that manganese functions in an indirect

manner in plants by its action upon the oxidation of iron. Hopkins (39) also noticed slow growth of *Lemna Minor* with iron and no manganese.

Bortner (11)) in 1935 observed chlorosis produced in tobacco plants by manganese in concentration of 15 p.p.m. in the nutrient solution, and noticed the antidoting effect of phosphorus. On the other hand, Sherman and Harmer (72) in 1941 found symptoms of manganese deficiency in oats manifested by specks and chlorosis which were prevented with the application of manganese.

Hopkins, Pagán and Ramírez-Silva (40) in 1944 found increase in growth of beans and tomatoes when manganese in soil was immobolized in the soil, and still more growth if iron humate was added. Marked detrimental phototropic action was noticed with excess supply of manganese, and in this effect, the antidoting action of iron was very effective.

Arnon (3), in his report of a review of the research done in mineral nutrition in plants for the year 1943, presents the following hypothesis offered by Somers and Shive: The cells of plants can tolerate only a certain definite concentration of iron which is of ferrous valence. The function of manganese is to regulate the concentration of ferrous ion. Manganese ions oxidize ferrous to ferric ions which precipitate in the form of "ferric-phosphorus organic complex," rendering iron physiologically inactive.

3. *Copper*

Copper is widely distributed in plants in considerable quantity; but according to research done it has stimulating action only at very low concentration, and it is generally toxic to green plants. The content of copper in pineapple fruits, according to an analysis shown by Beeson (8), is about 8 milligrams per kilogram. McHargue (59) reported in 1925 the copper content in various plants and plant parts as ranging from traces to 46 parts per million.

Plants respond to adequate copper treatments, as explained by Miller (61), showing increase in vigor, yield, quality, and control of chlorosis. He quotes the work of Maquene and Demossy in 1920 where they show that copper is found in greatest abundance in cells that are active in growth, and that its translocation is controlled by metabolic processes.

In the raw peat soils of the Everglades of Florida, Allison, Bryan and Hunter (2) in 1927 found copper to be a specific limiting factor, giving response in growth and production in a remarkable way when 30 and 50 pounds of copper sulphate per acre were applied to the soil.

Miller (61) gives a review of outstanding research done up to 1945 with copper and he points out the beneficial effect in some crops like onions, and in some fruit trees, when used as a fertilizer or as spray.

Hopkins (38) found in 1933 no increase in growth attributable to additions of copper to culture of *Lemna* and *Chlorella.*

Skoog (76) claims that copper may be related to the respiratory process.

The essentiality of copper for many species has been recently demonstrated by Hoagland and others, as reviewed by Petrie (64).

Felix (21) experimented in 1927 with onions and lettuce on the reclaimed muck lands of Central New York and found copper to be a limiting factor. Lack of copper produced a specific anatomical abnormality known as "rabbit ear". Onions fertilized with $Cu\ SO_4$ produced better colored and thicker scales.

It should be noticed that according to the findings of Waddell and Steenbock (82) in 1929, copper is regarded as a necessary adjunct to iron in the regenerated of anemia in animals. This may be considered as parallel to its effects in chlorophyll regeneration. Schappelle (71) claims that copper at a rate of 2 p.p.m. in the nutrient solution controlled a root fungus that caused stunting of the pineapple plant.

The so-called copper enzymes and copper containing proteins should, in part, show the relation of copper to respiration and oxidation processes in plants.

4. *Zinc*

The effect of zinc on plant metabolism is one of the most interesting phases of the field of plant nutrition.

The essentiality of zinc in corn plants was recognized, according to Miller (61), by Maze in 1915, and by Somer (77) in 1928, who noticed abnormalities in the growth of buckwheat and sunflower, and in the flowering of *Vicia faba.*

Bertrand and Andreitcheva (9) in 1933 considered the zinc content correlated with a high chlorophyll content.

According to Miller (61) zinc deficiency caused the plant disease called "little leaf," as demonstrated by works of Chandler, Hoagland and Hilbard in 1933, on peaches, apricots, tobacco, squash, corn, mustard, tomatoes and other plants.

Mowry and Camp (62) in 1934 found that spraying with zinc sulphate, or its addition to soil, made tung trees recover from bronzing.

Chapman, Vanselow and Liebig (18) produced mottle leaf by omitting zinc from culture solutions. The "mottle leaf" disease in citrus orchards is caused undoubtedly by zinc deficiency. Hoagland (34) describes the fight against this disease in California during twenty years, and says that not a good clue to its cause has been found yet.

Spraying with appropriate zinc compounds, he says, is effective and commercially practical. In Florida, the disease on pecans called "rossette," in Australia a disease of pine trees, and in Hawaii pineapples showing distorted blades, are conditions remedied by zinc sprays. It has been observed that for various reasons zinc in the soil is sometimes not made available to plants. It might be fixed to soil colloids. Certain soil organisms are a recognized factor in the non-availability of zinc by competing with the plant. Some plants have more capability than others for absorbing zinc when it is in a low supply from nutrients. Certain plants like alfalfa show a high ability to absorb zinc from the nutrient media.

Hoagland (34) considers that the quantitative requirement of zinc, as well as the deficiency symptoms, are in part governed by climatic or seasonal factors. High intensity of light aggravates the zinc-deficiency symptoms. (This is an important factor in tropical agriculture.) According to Hoagland (34), and the work of Skroog (76) about this phototropic action of zinc, auxin formation in plants is connected with zinc nutrition. Auxin breakdown is promoted by short-wave light.

The translocation of zinc is effected through the breakdown of the zinc protein compounds under the action of reduced light, thus releasing the zinc which is transplanted to regions of active growth. So, zinc is directly or indirectly connected with protein synthesis in plants. As it does not undergo reversible valence changes, its action in oxydation-reduction systems, if any, must be an indirect one, or due to its influence upon oxidizing enzymes and its interrelation with iron. Hence, zinc is related to respiratory processes and the maintenance of normal concentration of auxin in tissues as claimed by Skoog (76).

Thatcher (80) believed that copper and zinc are mutually counterbalancing catalyzers for hydrogen exchange, as shown by their strikingly opposite effect upon reversible oxidation-reduction reactions of both glutathione and ascorbic acid.

Leaf chlorosis in grape fruit trees in Puerto Rico, resembling the "mottle-leaf" in California and the "frenching" in Florida, was successfully controlled by Jensen (44), at the Federal Agricultural

Experiment Station of Puerto Rico, by spraying with zinc sulfate solution. Pineapple, under certain conditions of zinc deficiency, according to Nightingale (63) in 1942, show characteristic spots or blisters from which they recover by spraying with zinc sulfate solution.

As quoted by Beeson (8), a pineapple fruit analysis showed 20 milligrams of zinc per kilogram. Willis (86) showed that during the last fifteen years experimentation on this micronutrient element has demonstrated the essentiality of it for the normal growth of green plants, and its deficiency as causing characteristic chlorosis, mottle leaf or frenching, and "rossete" or "little leaf" in fruit trees.

5. *Aluminum*

Aluminum is very abundant in soils. It has been found in all plants that have been analyzed but, as a rule, the percentage of aluminum in plants is very low. It may thus be considered a micronutrient element. Grains and vegetables analyzed by Meyers and Voegtlin, as quoted by Miller (61), contained from 0.045 per cent dry basis in wheat flowers, up to 0.996 per cent in cotton seed. As to the role of this element in the growth and production of plants, Miller (61) reviewed the works of Yamano in 1905, who found injurious effects caused by 0.2 per cent ammonium alum on wheat and rye grown in nutrient solutions, and 0.8 per cent to be a fatal dose. Prianishnikov, in 1911, grew wheat, oats, barley, peas and buckwheat in sand cultures fertilized with aluminum phosphate and calcium carbonate alone. Baguley found in 1912 the iron and aluminum phosphate combination to be better. Kratzman observed in 1914 toxic effects of 0.005 per cent concentration of aluminum salts. Others, in experiments done after these, have found toxicity of aluminum salts at certain low levels of concentration in the nutrient media.

The soil-plant aspect of aluminum has been studied more than others. In fact, considering soil work, aluminum shows a great complexity in relation to other elements, it being one of the principal components of soils and soil colloids. Its availability is greater at lower pH.

Schapelle (71) showed beneficial action and recovery from injuries brought to pineapple plants grown in nutrient solutions lacking in aluminum. But Abbot (1) found in 1913 aluminum to be a toxic agent in the marsh regions of peaty sand, and also in culture solutions.

Barnette (6) in 1923, using solution cultures and upon observing the toxic effects of aluminum ions, determined that such toxicity was not due to acidity per se, but to the hydrolysis of aluminum salts.

The function of aluminum within the cell of the plant is ignored yet. Miller (61), reviewing the work of Fluri in 1907, mentioned the consideration that aluminum has an indirect effect in starch disappearance from the cell by increasing protoplasm permeability, diastatic action, and slowing photosynthesis.

Stocklassa (79) found in 1911 that aluminum and manganese together stimulated growth of several species of plants.

Blair (10) observed in 1923 the detrimental effect of soluble aluminum in soils upon roots. McGeorge (57) reported in 1925 that he noticed toxidity of aluminum on roots, in culture solutions, at the pH of acid soils. Haas (35), nevertheless, observed beneficial effect of aluminum in solution cultures of lemon, leafy-twig cutting, when a good supply of phosphorus is present.

Burgess (15) determined, 1923, the availability of aluminum in some soils. At pH 4 to 5 he found 388 parts per million while at pH 5 to 5.8 it was lowered to 36 parts per million.

Arnon (3), in a review on plant nutrition for the year 1945, says that Liebig, Vanselow and Chapman claim that they found that aluminum at low concentrations counteracts copper toxicity in citrus grown in culture solutions. It seems, according to them, that the case of the beneficial action of aluminum depends on its action against the toxicity of copper.

At high concentrations (2.5 to 5 p.p.m.) aluminum gave a curious stimulation of root growth accompanied by depression of top growth. In the absence of aluminum, excessive copper caused a brownish appearance in citrus roots and short swollen laterals which gave the roots a dwarfed, knotty, and unhealthy appearance. Top growth often exhibited iron chlorosis.

6. *Boron*

Boron is the micronutrient element that has received the greatest attention; and still the mechanism of the function of this element in plant growth is hidden to us. As claimed by Chapman (17), up to now we have not passed beyond the knowledge of the effects of its deficiency upon the meristematic tissue, and its interrelation with calcium. There is a marked similarity between the symptoms of calcium and boron deficiencies. Boron is widespread in the plant kingdom, it probably occurs in all green plants. Since 1857 its

presence was detected in plants by Whittstein and Apogier (88), followed by Baumert (7) in 1888, Hotter (42) in 1890, and Jay (43) in 1895, who analyzed various plants and believed in the universality of boron in the plant kingdom.

The study of the influence of boron upon plant growth called the attention of many investigators. Sand, solution, and soil-culture experiments were made by Augulhon (4) in 1910 and by Brenchley (12) in 1914. Their findings point toward the beneficial effect of boron when supplied to the plant in the right amount. The work of Warington (84) in 1923 on boron compounds on beans, in solution cultures and field experiments, was the beginning of the consideration of the mechanism of boron nutrition in plants. She pointed to the catalytic action and its effect on meristematic tissues.

The effect of boron nutrition on nodule formation in leguminous plants was studied by Brenchley and Thornton (13) in 1925. They found beneficial action on the production of nodules as due to the anatomical conditions of the plants with good boron nutrition. From there on, the boron requirements for nutrition of many crops have been studied, as well as the symptoms of deficiency and toxicity for different plants.

Miller (61) reviews the studies made on boron deficiency, and from the works of Warington in 1926, points out that disintegration of phloem and ground parenchyma, poor development of the xylem, and hypertrophy, discoloration, and disintegration of cambial cells occur when boron is omitted from the nutrient solution. Growth is arrested in the meristematic tissues of root tips, as found by experiments of Sommer and Sorokin in 1928. The effects of boron deficiency in tomato plants, "the guinea pig of the plant nutritionist," are very noticeable: death of terminal growing points of stem, characteristic brittleness of the stem and petiole, and poor brownish roots.

That the function of boron cannot be performed by other elements was found by Warington in 1927. She tried fifty-two other elements. Sugar beet and alfalfa are plants very much affected by lack of boron, and show specific deficiency symptoms. Boron, indeed, will show harm on plants when supplied in excess, bringing about chlorosis. This is probably due to its action against the solubility of iron, as claimed by Rodríguez in 1935. (66[a]) An effect of boron toxicity is stimulation of undifferential cell division causing abnormal growth in the regions of its maximun effect.

The essentiality of boron for higher plants is no longer open to dispute. Brenchley (12) and Warington (84) proved that boron

is absolutely indispensable for satisfactory growth of many crops. Both report on the retardation of the development of meristem tissues and discoloration of the stem in plants as specific symptoms of boron deficiency.

Eaton (20) made in 1944 careful observations on the nutritional effects of boron, and noticed that in most plants it accumulates in soluble but largely immobile form. He suggests that boron becomes attached to some large molecule which, though soluble, is unable to pass through the plasma membrane of the mesophyll cells. Owing to this immobility of boron in leaf tissue, plants may show symptoms of boron excess in old leaves, and yet not be supplied with excess. Thus, there may be an overlapping of beneficial and toxic effects in the same plant. High-light intensity may be responsible for its immobility in the leaves. Boron deficiency is aggravated by increase of calcium in the nutrient solution, but its toxicity is lowered. Variations in potassium concentration affect indirectly boron deficiency and toxicity due to the effect of potassium on calcium absorption.

III — OBJECT OF THE WORK

It is the object of these experiments to study:

1. The effect of iron, manganese, zinc, copper, aluminum and boron on the growth and production of pineapples.
2. The antidoting effect of iron on manganese toxicity.
3. The mutual action of these micronutrient elements, and their deficiency or toxicity as affecting root growth, leaves, flowering, fruiting, yield, and quality of the crops.
4. The causative agents of pineapple chlorosis.
5. To verify the data already obtained in other experimentation in this field.
6. To guide future experimentation with pineapple plants along this line.
7. To suggest possible methods to remedy injuries on the pineapple plants as caused by malnutrition of the plant.

IV — EXPERIMENTAL

A. General Plan

Solution-culture methods were used in this experiment with a formula of macronutrient elements already found to be good for growing pineapple plants. The facilities of the greenhouse and hydroponic equipment of the Agriculture Experiment Station of the University of Puerto Rico (Fig. 2 and 3) as designed by Schapelle (71) were used. These experiments are a part of a research project of this Station.

The experiments consisted of two series of treatments. One series had nine treatments of micronutrient elements, to study the individual effect of the micronutrient elements when added to the culture solution. Treatment number one had no micronutrient elements added. This treatment showed the combined effect of all the reserve micronutrient elements in the planted slips. It served as a check on the other treatments. Treatments 2, 3, 4, 5, 6, and 7 corresponded, respectively, to additions of iron, manganese, boron, copper, zinc, and aluminum as the only micronutrient elements added to the nutrient solutions. These showed the beneficial effect of the presence of these elements, or their toxic effect, when acting independently at the concentrations added, as compared with treatment 1, to which no micronutrient elements were added. The eighth treatment contained all the micronutrient elements in the concentrations used in the previous treatments. This treatment was another check on the other six treatments. Treatment 9 was the same as 8 except that copper was not added. This showed the effect of lack of copper and was intended to check the results on root injury shown by lack of copper in the experiments of Schapelle (71). This treatment may be used to examine the effect of copper added in treatment 5 and, from this, infer its effect shown in treatment 8 where all micronutrient elements were added, and those of the following series.

Treatments 1 to 9 were designated as follows:

Treatment 1 as -ME (no micronutrient elements added)
Treatment 2 as Fe (iron added)
Treatment 3 as Mn (manganese added)
Treatment 4 as B (boron added)
Treatment 5 as Cu (copper added)

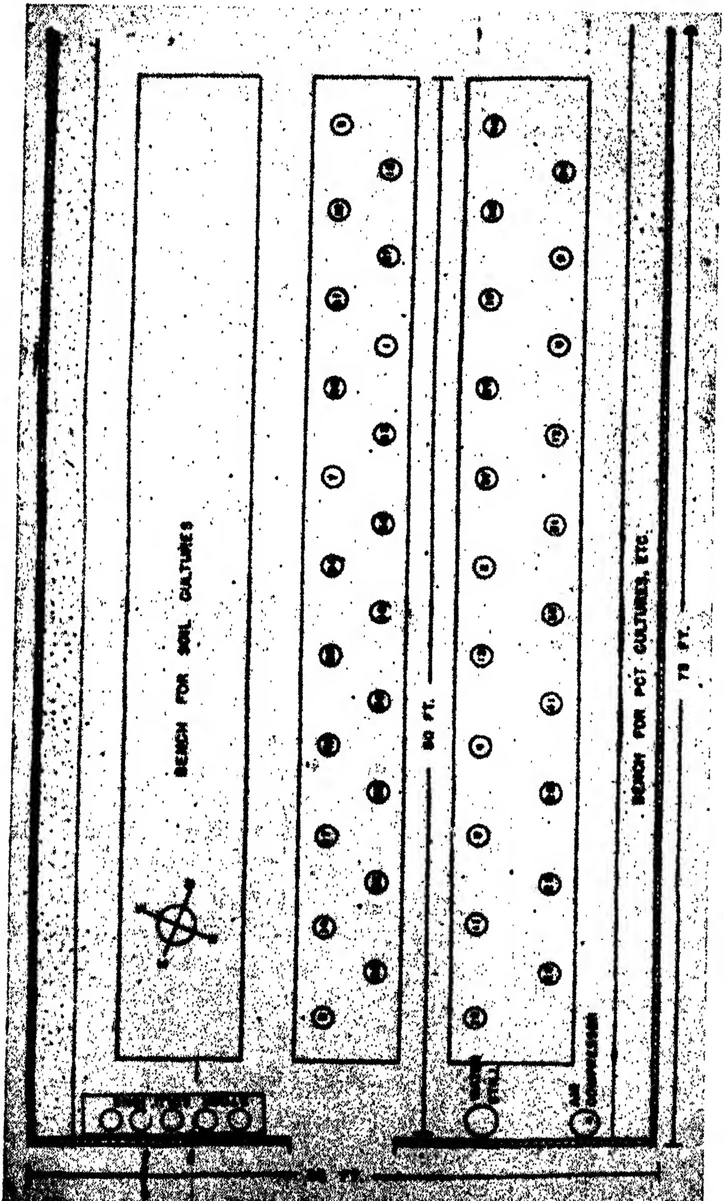


FIGURE 2.—Floor plan of the greenhouse showing the arrangement of the solution cultures. The numbers and position of the pineaple plants are shown within the circles.

Treatment 6 as Zn (zinc added)
Treatment 7 as Al (aluminum added)
Treatment 8 as ME (all micronutrient elements added)
Treatment 9 as –Cu (all micronutrient elements minus copper)

The series of treatments 10 to 14 was intended to study the antidoting action of iron against the chlorosis-producing effect of manganese. For this purpose 5 p.p.m. of manganese were added to each one of the five treatments, and a different level of concentration of available iron was added in each. So, treatment 10 had no iron added, number 11 had one p.p.m. added, number 12 had three p.p.m., number 13 had five p.p.m., and number 14 ten p.p.m. All these treatments were supplied with 2 p.p.m. of copper to prevent root injury as reported by Schapelle (71). The micronutrient elements: boron, zinc, and aluminum, were added also, in a concentration of one half p.p.m. each, in order to prevent deficiency of these elements. Treatment 2 with 5 p.p.m. Fe added as the only micronutrient element may also be considered as a member of this series for the purpose of the study of the antidoting effect of iron. The study of the results of the treatments 1, 3, 4, 5, 6, 7, 8, and 9 will throw light on the study of the series of treatments 10 to 14 and viceversa.

The effect of aeration of the culture solution was studied. During the initial period of growth the solutions were not aerated.

For the purpose of this study, observations and data on roots, plant growth, chlorosis, flowering, fruiting, yield, and quality of fruit were taken.

B. Methods

1. *Nutrient solutions*

Pineapple slips of the variety "Smooth Cayenne," 12 inches long and selected for uniformity, were "planted" in culture solutions. All the treatments contained the following concentration of macronutrient elements:

SALT	*Grams per liter*
KH_2PO_4	0.1316
$MgSO_4 \cdot 7H_2O$	0.4100
$Ca(NO_3)_2 \cdot 4H_2O$	0.4720
NH_4NO_3	0.1260
K_2SO_4	0.1657

which furnish:

112.1 parts per million of K
30.0 parts per million of P
40.5 parts per million of Mg
80.1 parts per million of Ca

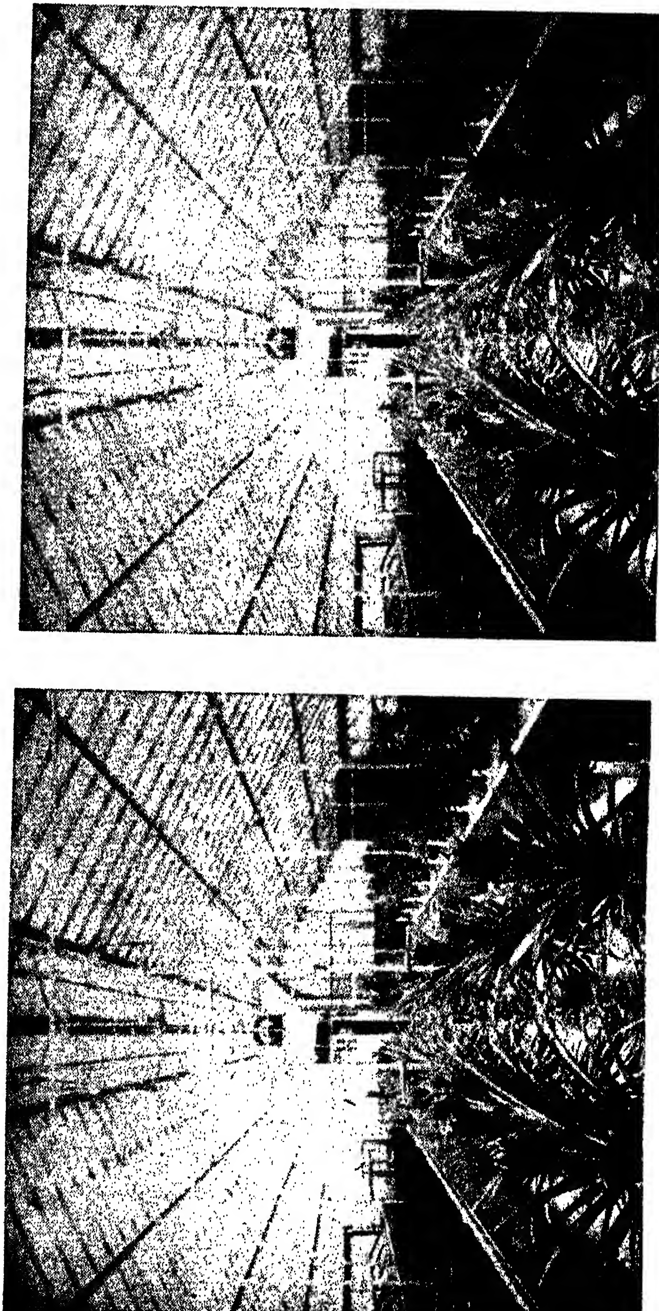


FIGURE 3.—Photographic views of the Greenhouse and the Solution Culture Experiment. Pineapple Plants, 493 days after planting. The air supply system for aerating the solution is shown.

83.6 parts per million of S
77.9 parts per million of Nitrate N
22.0 parts per million of Ammonia N

The following concentrations of micronutrient elements were added to the different treatments:

TABLE No. I

Treatment			Parts per Million					
No.	Elements	Jar Number	Mn	Cu	Al	B	Zn	Fe as $FeSO_4$
1.	All M. E.	1- 2- 3						
2.	Fe	4- 5- 6						5
3.	Mn	7- 8- 9	2					
4.	B	10-11-12				1		
5.	Cu	13-14-15		2				
6.	Zn	16-17-18					2	
7.	Al	19-20-21			1			
8.	All M. E.	22-23-24	2	2	1	1	2	5
9.	Cu	25-26-27	2		1	1	2	5

THE IRON-MANGANESE SERIES

No.	Elements	Jar Number	Mn	Cu	Al	B	Zn	Fe as humate
10.	5 ppm Mn.	28-29-30	5	2	½	½	½	0
11.	5 ppm Mn Fe 1 ppm.	31-32-33	5	2	½	½	½	1
12.	5 ppm Mn Fe 3 ppm.	34-35-36	5	2	½	½	½	3
13.	5 ppm Mn Fe 5 ppm.	37-38-39	5	2	½	½	½	5
14.	5 ppm Mn. Fe 10 ppm.	40-41-42	5	2	½	½	½	10

The solutions of micronutrient elements were prepared as follows:

Element	Parts per Million of the Element	Salt used C. P.	Grams of Salt per Liter
Mn	2	$MnSO_4 \cdot H_2O$	0.00615
Cu	2	$CuSO_4 \cdot 5H_2O$	0.00785
Al	1	$Al_2(SO_4)_3 \cdot 18H_2O$	0.012355
B	1	$K_2B_4O_7 \cdot 5H_2O$	0.007476
Zn	2	$ZnSO_4 \cdot 7H_2O$	0.008796
Fe	5	$FeSO_4 \cdot 7H_2O$	0.02489

In every case stock solutions were prepared, so as to furnish the requisite amount of micronutrient elements, by using a definite adequate aliquot for the corresponding jar used in each treatment. The solution of ferrous sulphate was prepared in small quantities, at the required moment, to be used immediately. It was slightly acidified with sulfuric acid to prevent hydrolysis. Distilled water and C.P. chemicals were used always.

The iron humate added to treatments 10 to 14 was prepared according to the method of Horner, Burk and Hoover (41), and taking into consideration the recommendations of Burk, Lineweaver, Horner and Allison (16).

The macronutrient formula used in these experiments is a modified form of the solution used by Sideris, Krauss, and Young (74). It was used successfully by Schapelle (70, 71) in his work with pineapple plants.

The pH values of the nutrient solutions were determined periodically, by means of a Leeds and Northrup Universal glass electrode potentiometer. A pH value near to 4.5 was maintained by adding the required amounts of a normal $H_2 SO_4$ solution or a dilute solution of $Ca(OH)_2$, according to the change in pH of the nutrient solutions. According to Schapelle (71), pH 4.5 is the optimum value for growth of pineapple plants in culture solutions.

2. *Method of growing the pineapple plants.*

The pineapple slips selected for these experiments were planted in quart culture jars of good-grade white glass which were prepared with suitable wooden lids with a hole in the center big enough to hold the slips. Three cultures were planted for each of the fourteen treatments, so, there were forty-two culture jars. These were distributed at random in the greenhouse. The arrangement and number of the treatments are shown in figure 2. Two photographic views of the experiments, when the plants were already fruiting, are shown in figure 3. The jars were buried in sand to exclude light rays from the solutions.

Table I shows the concentrations of micronutrient elements used for each treatment and the jars numbers.

The macronutrient solution used was the same for all the treatments. Its concentration is shown on page 216. The solutions were changed every month. The concentration of the solution of macronutrient elements was reduced to one half from the 214 day on.

On the 84 day after the slips were planted, the plants were transferred from the quart jars to wide-mouth gallon jars because the root system had grown already too big for the quart jars. For the same reason they were again transferred to 17-liter pyrex jars on the 214 day. The lids of these jars were made of wood and the center holes were lined with cork rings to hold the plants in place.

The roots were carefully drained of the residual solution in them every time that the solutions were changed. To change the solution, the plant was removed together with the lid and the jar was emptied

with a siphon. It was then cleaned of any solid residue and of the old solution. Then the jar was filled to about one half its volume with water. The corresponding aliquots of the stock solution of nutrient elements were added independently one by one, dissolving each one after added. The volume was completed to the 17–liter mark, and the plant put back to its place. The solution was brought to the 17–liter level with distilled water every day.

While the plants were growing in the quart jars, that is, during the first 83 days, the solutions were not aerated. From the 84 day on air was bubbled continuously through the solution. The air bubbles were passed at a uniform rate through all the jars, as exactly as possible. An automatically-pressure-controlled electric air compressor furnished the supply of air. Glass tubing was used to pass the air from the main air pipe into the solutions (see Figure 3).

The greenhouse, where this experiment was set up, was well ventilated by means of an electric fan located near the roof at one end of the building. (See Figure 3).

3. *Observations and data to be obtained.*

The plants were observed every day to note: (*a*) any change in conditions of growth, (*b*) root volume and development, (*c*) date of appearance and magnitude of chlorosis, (*d*) necrosis in leaves, (*e*) intensity of greenness, (*f*) condition and pH of solutions, (*g*) date of the beginning of blooming and of attainment of mature fruit, (h) weight and size of fruit and crown when harvested, (*i*) analysis of the juice of the fruit ripened out of the plant, for reducing sugars, total sugars, total acidity and density.

4. *Chemical methods of analysis.*

(*a*) *Extraction of juice*

The ripe pineapple fruits were carefully peeled from the non-edible rind, and the whole fruit cut in pieces and subjected to 500 pounds pressure per square inch in a Carver laboratory press. The juice expressed from the whole pineapple fruit was collected for analysis.

(*b*) *Density determination*

The degree brix of the juice was determined using brix hydrometers calibrated at 20°C. The readings made were corrected to 20°C, using the scale for corrections attached to the thermometer within the body of the hydrometer.

(c) Determination of reducing sugars

The official method (75) for the determination of reducing sugars and total sugars was used, that is, Lane–Eynon general volumetric method, as described in section XXXIV 32 of the Official and Tentative Methods of Analysis (75). This method uses Soxhlet's modification of Fehling's solution, as reagent. Solution (A) consists of 34.639 grams copper sulfate ($CuSO_4$ $5H_2O$) dissolved in distilled water and diluted to 500 ml., filtered through prepared asbestos in a Cooch crucible. Solution (B) is the alkaline tartrate solution, and is made by dissolving 173 grams of Rochelle Salts and 50 grams of sodium hydroxide in distilled water and diluted to 500 ml., then allowed to stand for two days and filtered through prepared asbestos. This solution was standardized according to the procedure in Section XXXIV, 33 of the Official Methods of Analysis (75), taking 5 ml. of solution (A) and 5 ml. of solution (B).

The determinations were made on a portion of the freshly extracted juice diluted 1 to 10. A one-per-cent-aqueous solution of methylene blue was used as the internal indicator. A preliminary incremental titration was made on the first sample, and the determinations made in triplicate, according to Section XXXIV, 34 (75), following a similar procedure to the one used for standardization of the reagent.

The calculation of the reducing sugars was made using Table XV Section XLIII of the Official Methods (75), taking the factors in the column for solutions having one gram of sucrose in 100 ml. of the juice solution used for titration. Of course, the readings of the volume in ml. of solution required to react to the end-point with the amount of reagent used, was divided by the concentration factor of the reagent's solution, to obtain the ml. that would be required for a reagent with a concentration factor of 1.0.

As the values thus obtained give the grams of reducing sugar in 100 ml. of the solution of juice used in the titration, multiplying these weights by ten will give the grams of reducing sugar in 100 ml. of juice. To obtain the percentage of reducing sugars weight in the juice, the weight in grams of reducing sugars in 100 ml. of juice is divided by the specific gravity 20°/4°C of the juice as determined from the brix reading, from Spencer (78).

(d) Determination of Total Sugars

Total sugars were determined promoting total inversion by adding 2 ml. of concentrated HCl (specific gravity 1,1029 at 20°/4°C)

to 10 ml. of the freshly extracted juice in a 100 ml. volumetric flask, left overnight for total inversion. Then the solution was neutralized with NaOH and brought up to the 100 ml. volume. From this, 10 ml. were diluted to 50 ml. and analyzed for reducing sugar by the same method given above for the fresh uninverted juice. The weight in grams of invert sugar in 100 ml. of the titrated solution of juice as calculated from the factors of Table XV, in the Official Methods (75) on the first column for no sucrose, must be multiplied by 50 to account for the two dilutions made: 10 to 100 and then 10 to 50. This gives the weight in grams of total sugars as invert sugar in 100 ml. of fresh juice. This value divided by the specify gravity 20°/4°C gives the percentage by weight of total sugars, as invert sugar in the juice.

(e) *Total Acidity*

The total acidity was determined by titrating the freshly extracted juice against a standard NaOH solution, taking 10 ml. of the juice. Phenolphthalein was used as the indicator.

According to E. K. Nelson of the Bureau of Chemistry, U.S.D.A., quoted by Hericksen (33), citric acid constitutes about 87 per cent of the total acids of pineapple juice. The acidity of the juice is calculated on the basis of per cent of citric acid in juice. This is done by multiplying the normality of the acid in the juice by one tenth of the gram equivalent weight of citric acid, that is, 6.4, and dividing by the specific gravity 20°/4°C of the juice so as to reduce it to gravimetric basis.

C. *Results and Discussion of the Effect of Micronutrient Elements.*
1. *Chlorosis*

The observations on the chlorosis shown by the plants, are expressed numerically in table II, indicating the total severity of chlorosis per treatment of three plants, the day of appearance, and of any change in the severity.

The numerical evaluation has been made on the following scale of values per plant:

Slight chlorosis	1.0
Medium chlorosis	2.0
Strong chlorosis	3.0
Very strong chlorosis	4.0
Necrosis	5.0
Very strong necrosis	6.0
Death of each plant	8.0

TABLE No. II

OBSERVATIONS ON CHLOROSIS OF PLANTS EXPRESSED NUMERICALLY FOR THREE PLANTS

Number	Treatment	Days after planting													Weighted averages 414 days
		88	90	94	97	101	107	114	119	132	143	170	214	414	
1	M. E					1	2	2	3	4	5	6	6	6	4.2
2	Fe														0
3	Mn	1	1	2	2	3	5	6	6	6	10	10	10	10	7.1
4	B			1	1	2	2	3	3	4	5	8	8	8	5.3
5	Cu			1	1	2	3	3	6	9	14	14	14	14	9.2
6	Zn					1	1	2	2	4	4	5	5	5	3.5
7	Al			1	1	1	2	2	3	3	3	4	4	4	2.6
8	M. E.														0
9	-Cu											1	1	1	0.6
IRON-MANGANESE SERIES—5 PPM OF MANGANESE															
10	Fe 0 ppm	3	3	6	9	12	12	12	12	12	16	18	18	18	13.0
11	Fe 1 ppm														0
12	Fe 3 ppm														0
13	Fe 5 ppm														0
14	Fe 10 ppm														0

BASIS OF NUMERICAL EVALUATION PER PLANT

slight chlorosis	1.0	very strong chlorosis	4.0
medium chlorosis	2.0	necrosis	5.0
strong chlorosis	3.0	strong necrosis	6.0
dead plant	8.0		

See Table I for concentration of micronutrient elements in each treatment.

For the purpose of comparison on the chlorosis produced by each treatment, averages have been calculated as "weighted averages". The magnitude of the severity is multiplied by its duration in days, and each summation of these products is divided by 414, that is, the number of days from the time of planting to the time of blooming of the plants.

The following method was used, taking treatment three as an illustration.

According to table II, in this treatment chlorosis appeared on the 88 day.

The chlorosis value	1	lasted	6	days
The chlorosis value	2	lasted	7	days
The chlorosis value	3	lasted	6	days
The chlorosis value	5	lasted	7	days
The chlorosis value	6	lasted	29	days
The chlorosis value	10	lasted	271	days

Multiplying each value of intensity of chlorosis by the number of days it lasted, then this gives:

Without chlorosis 88 days

1	multiplied by	6	equals	6
2	multiplied by	7	equals	14
3	multiplied by	6	equals	18
5	multiplied by	7	equals	35
6	multiplied by	29	equals	174
10	multiplied by	271	equals	2710

Total "chlorosis days" 2957
Total number of days 414
Average per day (three plants) 7.1

The average is calculated on the total growing period of 414 days. Some treatments showed chlorosis before others. Averaging for the total period of growth takes this into account.

Apart from the information given in table II, the following observations were made:

a. Treatments 2, 8, 11, 12, 13, 14, that is, all the treatments containing iron, showed plants with a good green color, especially treatment 2 that had iron as the only micronutrient element added.

b. The three plants of each treatment showing chlorosis were not affected equally in each case, some showed very slight chlorosis too low to be evaluated. The variations in reserve iron in the planted slip may be the chief reason

for this. The table gives information about the starting date, intensity in each case, and the rate of increase.

c. One plant in treatment 10 never bloomed and finally died of an extremely strong necrosis.

d. One of the plants of (copper) treatment number 5, showed also strong necrosis but was able to survive and bear fruit.

e. Attention should be given to the fact that treatment 3 had only two parts per million of manganese, while number 10 had five parts per million and the other micronutrient elements.

f. The degree of greenness in treatments 11 to 14 increased with the increase in iron in these treatments, but was not as high a green color as in number 2 that had iron as the only micronutrient element added. (Treatments 10 to 14 had other micronutrient elements added besides the manganese and iron. See Experimental Methods).

Discussion of the results on the chlorosis produced

All the treatments with iron added: 2, 8, 9, 11, 12, 13 and 14, were exempt from chlorosis.

Treatment 2, with iron as the only element added at 5 ppm, was the greenest of all treatments. Treatment 1, with no elements added, showed chlorosis; so, the iron added in treatment 2 was enough to prevent the chlorosis caused by chlorosis-producing elements in reserve in the planted slip. In other words, the reserve iron in the slip was not sufficient to counteract the chlorosis-producing tendency of the other elements through the whole period of growth. Extra nutrition of iron was required, as shown in treatment 2, to prevent chlorosis. Treatment 2 was greener than treatment 8 where the other elements were added and in which still no chlorosis was produced.

Treatments 10, 11, 12, 13, and 14 of the iron-manganese series, showed more definitely the counteracting action of iron against the chlorosis-producing action of manganese, and possibly of the other elements added in this treatment. While treatment 10 showed marked necrosis (one plant could not survive); treatment 11 (only one part per million of iron added) produced green chlorosis-free plants. Treatment 10 had five parts per million of manganese added and other micronutrients in smaller concentrations. (See Experimental Methods.) As will be shown later, these other elements have some tendency to produce chlorosis, especially copper.

Figure 4 shows plants under treatments 10 and 11, on the 102 day after planting. Notice that the plant of treatment 10 was strongly chlorotic, and that of treatment 11 was normal. Figure 5

FIGURE 4.—Photographs of plants, 102 days after planting.
Treatment 10, above. Micronutrient elements added to the culture solution: 5 ppm of Mn, 2 ppm of Cu, ½ ppm of B, ½ ppm of Zn, and ¼ ppm of Aluminum. The plant is strongly chlorotic and necrotic.

Treatment 11, below. The same micronutrient elements as above but with one ppm of iron added. The plant is growing normally.

shows plants of the same treatments 493 days after planting. The plant of treatment 10 was almost dead and that of number 11 produced a normal fruit with a beautiful crown, a good sign of vigor and good quality.

The appearance of treatments 11, 12, 13, and 14, showed an increase in greenness with the increase of iron. No detrimental effect due to iron was noticed in any one of the treatments where iron was added.

The chlorosis produced by toxic concentrations of iron mentioned by Arnon (3), and the necessity of certain concentration of manganese to bring about a balance of the ferrous and ferric ions for proper chlorophyll formation, are not shown in these treatments. It may be that in the case of treatment 2, where iron was the only element added in five parts per million, the concentration was low enough, or the reserve manganese in the slip was at the right level; but in any case, there were no signs of iron toxicity. There are good reasons to believe that the toxicity of iron, if any, would be at a very high level in pineapple plants.

Treatment 5, that had copper as the only minor element added, showed strong chlorosis and even necrosis. This points out the conclusion that copper produces chlorosis at certain levels of concentration in the nutrient solution, if in the absence of iron. These results show the action of copper stronger even than that of manganese, which in treatments 3 and 10 induced chlorosis very markedly and in proportion to its concentration in the nutrient solution. See figure 6.

Boron also produces chlorosis when added to the nutrient solution in the absence of iron, or in the presence of insufficient iron to antidote its action. Compare treatment 4 with 1.

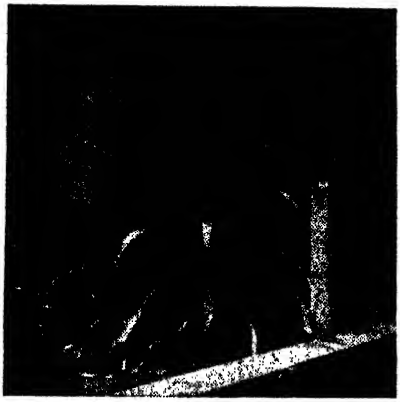
The above conclusions can be shown numerically as follows:

The average of the "weighted averages" of chlorosis of all treatments from 1 to 9 having iron, i.e., treatments 2,8,9, is 0.2; while the average for all treatments 1, 3, 4, 5, 6, 7 with no iron added, is 5.3. Also the chlorosis produced by treatments 1, without micronutrient elements added; 3 with manganese; 4 with boron; 5 with copper; and 6 with Zn; make a total of averages of 31.9. This was antidoted by 5 p.p.m. of iron added in the treatment 8, value 0, in which all the micronutrient elements were added.

Evidence is given to definitely establish that, in the pineapple plant, iron antidotes the action of the chlorosis-producing elements copper, manganese and boron, when these are in a toxic concentration in the nutrient solution.

The treatments of zinc and aluminum showed beneficial effect against chlorosis. Treatments 6 and 7 gave lower values of chlorosis than treatment 1.

PINEAPPLE PLANTS, 493 DAYS AFTER PLANTING



A. Treatment 1.
No micronutrient elements added.

B. Treatment 3.
2 parts per million manganese added.

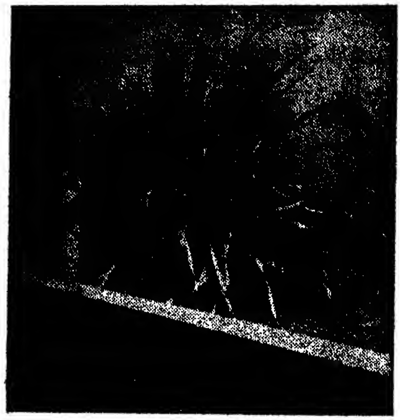
C. Treatment 10.
No iron added.

D. Treatment 11.
1 ppm of iron added.

FIGURE 5.—Treatments 10 and 11, each contain: 5 ppm of manganese, 2 ppm of copper, ½ ppm of zinc, ½ ppm of boron, ½ ppm of aluminum.

Note that "C" is strongly chlorotic and necrotic, and has not flowered yet; the plant in "D" is heathly, and produced a fruit better than in "A" and "B". The plant, fruit and crown of "A" are better than those in "B". The presence of iron in "D" counteracted the detrimental action of other micronutrient elements affecting the plants in "A", "B" and "C".

PINEAPPLE PLANTS, 493 DAYS AFTER PLANTING



E. Treatment 5.
2 ppm of copper added.
The plant is necrotic. The fruit and crown are very small.

F. Treatment 9.
No copper added.
The plant is healthy. Fruit and crown are normal.

FIGURE 6.—Compare the plant in "E" with the plant in "D", figure 5. The detrimental effect of copper on plant and fruit is noticed.

2. *Root Growth*

The roots started to come out on the eighth day. On the 79 day they were rather crowded in the quart-jar vessels and were to be changed to gallon jars.

Browning or burning of the root tips was noticed in some treatments. The severity of this injury is expressed numerically in table III. This root-rot injury in pineapple roots was noticed by Schapelle (71) in cultures deprived of copper.

As is shown in table III, up to the 79 day the solution had not been aerated, and on that day the root injury due to this burning or browning of the tips was noticed in the absence of iron and copper.

In nonaerated solutions, copper showed the greatest beneficial action. Treatment 5, in which copper was added, showed almost no injury; while treatment 9, with no copper added, showed a very high severity of injury.

Aluminum showed the highest intensity of injury to roots, in the nonaerated cultures. Zinc also showed injurious effects in nonaerated solutions. Compare the results of treatments 6 and 7 with treatment 1.

The aeration of the solution, as shown on the 108 day, tended to reduce the injury in all treatments. The aluminum treatment recovered rapidly and instead of the detrimental action a highly beneficial action was noticed. In the copper treatment it was the reverse, the beneficial action of copper turned into a detrimental effect. Zinc showed recovery also.

TABLE NO. III

OBSERVATIONS ON THE ROOTS

Treatment		Total Browning of Roots		Average volume in ml.	Appearance on the 149 day
Number	Elements	unaerated 79 day	aerated 108 day		
1	ME	6	6	125	Good
2	Fe	1	0	114	Very good
3	Mn	3	3	159	Good
4	B	4	4	137	Short
5	Cu	1	5	86	Hairless, stiff & brown
6	Zn	7	4	85	Good
7	Al	10	2	173	Very good
8	ME	3	3	72	Good
9	Cu	8	1	167	Very good
IRON MANGANESE SERIES. Mn. 5 p. p. m.					
10	Fe 0 p p m	1	0	77	Good
11	Fe 1 p p m	0	0	73	Good
12	Fe 3 p p m	0	0	101	Good
13	Fe 5 p p m	0	0	86	Good
14	Fe 10 p. p. m	0	0	70	Good

Table I gives the concentrations of nutrient elements in each treatment.

Numerical evaluation of browning based on: Very slight = 1, slight = 2, medium = 3.

Volume of roots obtained by displacement of water.

The iron treatments showed beneficial action with aerated as well as non-aerated solutions. Manganese and boron showed some beneficial action.

This interesting response of the micronutrient elements, as related to the aeration of the nutrient solution, points out that as far as root growth is concerned, an oxidation-reduction process plays an important role. It seems that iron and copper have a beneficial oxidizing action under anaerobic conditions; while aluminum and zinc do not show this property. On the other hand, the action of aluminum and zinc has a beneficial effect under the conditions of ample oxygen supply in aerated solutions.

The findings of Loehwing (54), Clark and Shive (19), and Bryant (14), as to the beneficial effect of nonaerated nutrient solution on root growth, should be conditioned by saying that copper or iron are required to be present.

The beneficial action of copper in raw peat soils, pointed out by Allison, Bryan and Hunter (2), may be attributed in part to the anaerobic conditions of these soils. The detrimental effect of aluminum on root growth, as noticed by Blair (10) Barnette (6), Abbot (1), and McGeorge (57), can be explained also as due to conditions of low oxygen supply in the nutrient solution. On the other hand, the beneficial action of aluminum as observed by Schappell (71) is due to the presence of a good supply of air.

The reports of Liebig, Vanselow and Chapman, as quoted by Arnon (3), on copper toxicity in citrus roots, and the stimulating action of aluminum, are confirmed by the results shown in these experiments as to the action of copper and aluminum on root growth under aerobic conditions. That is, aluminum and copper counteract each other under either aerobic or anaerobic conditions.

The volumes of roots, as shown in table III, point out that copper and zinc tend to inhibit root growth; while aluminum, boron and manganese appear to stimulate it. Iron does not show any particular effect, for treatment 2 showed about the same results as treatment 1.

The combined effect of copper and zinc tended to produce low volume of roots in treatments 8 and 10 to 14. Treatment 9 without copper showed the best volume.

3. *Flowering and fruiting*

The first plant to flower and bear fruit was one of culture treatment 14, with 5 p.p.m. of manganese and 10 p.p.m. of iron. The fruiting stalk appeared at the 214 day, and the mature fruit was harvested on the 323 day. Table IV shows the average day when

the flowering started, and the average day when the fully mature fruit was picked from the plant in each treatment. The average weight of the fruit at maturity with and without crown and the weight of the crowns are given for each treatment. The figures on table IV show very interesting results.

TABLE NO. IV

FLOWERING AND FRUITING

MATURE FRUITS—AVERAGE FOR THREE PLANTS

Treatment		Days Taken		Weight in Grams		
Number	Elements	To Flower	To give mature fruit	Fruit	Crown	Fruit & Crown
1	ME	424	536	1,033	389	1,422
2	Fe	423	534	1,170	274	1,444
3	Mn	423	539	1,130	263	1,393
4	B	494	611	1,165	275	1,440
5	Cu	519	624	863	258	1,121
6	Zn	450	555	853	246	1,099
7	Al	431	533	1,209	338	1,547
8	ME	405	533	1,067	199	1,266
9	Cu	431	529	1,353	357	1,710
IRON-MANGANESE SERIES--5 P. P. M. OF MANGANESE						
10	Fe 0 p. p. m.	570	675	521	160	681
11	Fe 1 p. p. m.	421	523	1,126	258	1,384
12	Fe 3 p. p. m.	412	519	1,133	319	1,452
13	Fe 5 p. p. m.	412	514	1,156	331	1,487
14	Fe 10 p. p. m.	409	509	1,230	376	1,606

See Table I for concentrations of elements in each treatment.

The treatments 11 and 12 showed flowering and fruiting earlier; and the more iron, the earlier.

Copper, boron, and zinc showed a retarding influence on flowering and fruiting, as shown in treatments 4, 5, and 6 as compared with 1. Copper exerted the most detrimental effect. See figures 5 and 6. It is remarkable that no retarding action was shown by manganese in treatment 3, thus showing that it is the retarding effect of copper, boron and zinc that have been antidoted by iron in treatments 8, 9, 11, 12, 13, and 14. The retarding action in treatment 10 may be attributed to the indirect effect of manganese-chlorosis and the retarding effect of other micronutrient elements added.

The treatments with iron showed the earlier flowering and fruiting, but it appears that iron and manganese have an additive action superior to their independent action. Compare treatments 2 and 3

where these elements are alone, one in each treatment, with 8 and 11 to 14, where they are together, and against the retarding influence of copper, boron and zinc.

The weights of fruits, either with or without crown, showed to be affected quite similarly to flowering and fruiting. The treatments of copper and zinc gave the lowest yield comparing treatments 5 and 6 with 1.

It should be pointed out that the minus-copper treatment 9 showed the highest yield. The aluminum treatment also gave a high yield. Iron and boron favored high yields also.

The production of fruits was not so badly affected by the injury on roots and by chlorosis when the injury did not reach the advanced stage of destroying the plant to a certain degree, as it did in the plus-copper treatment 5 and in the no-iron treatment 10. In the iron-manganese series the weight of crop increased with the increase in iron.

The desirable vigorous crown was at its best in the manganese and iron treatments, where increasing quantities of iron were added. The treatments without zinc did not show detrimental action on the crown. It was expected that treatments without zinc might give short crowns, Hopkins et al (40), connecting it with the "little leaf" disease in citrus, or any distortion in the leaves as discussed by Hoagland (34), due to lack of zinc in the nutrient solution.

It is noticed that the aluminum treatment produced very good fruits as to weight of the fruit and of the crown. This may be due to its beneficial effect on roots when aerated.

4. *Composition of the juice of the ripe fruits.*

Table V shows the degree brix of the juice, a figure approaching the per cent of total solids by weight in solution, called also "apparent gravity solids" in sugar technology. The total sugars in juice are expressed as invert sugar. The ratio of total sugar to brix has been calculated and multiplied by 100, so as to show the relation between sugars on the total (gravity) solids, and so as to give a figure independent of dilution. This may be called the "gravity purity of invert sugars". It is the figure that should give the best criteria of the quality of the juice as to its sugar content.

The percentage acidity is reported on the basis of citric acid as discussed in the Experimental Section. The percentage of reducing sugar in the juice is also given.

TABLE NO. V

COMPOSITION OF THE JUICE OF THE RIPE FRUITS

Treatment		Juice Analysis—Average for three Plants				
Number	Elements	Reducing Sugar %	Total Sugar as Invert Sugar %	Degree Brix	o/o of solids which are Sugars	Acidity as Citric Acid %
1	ME	2.75	10.70	15.7	68.2	0.73
2	Fe	2.61	9.80	13.1	74.8	0.67
3	Mn	3.02	9.34	14.7	63.5	0.76
4	B	3.29	10.84	14.6	74.0	0.68
5	Cu	2.46	9.06	12.7	71.3	0.66
6	Zn	1.95	7.60	11.5	66.0	0.88
7	Al	2.45	8.28	11.7	70.8	0.74
8	ME	3.73	11.48	14.8	77.5	0.61
9	-Cu	2.72	9.80	13.3	73.7	0.68
IRON-MANGANESE SERIES—5 P. P. M. OF MANGANESE						
10	Fe 0 p. p. m.	2.47	9.23	13.9	66.4	0.72
11	Fe 1 p. p. m.	4.38	9.28	12.6	73.7	0.61
12	Fe 3 p. p. m.	3.05	11.22	15.6	76.8	0.63
13	Fe 5 p. p. m.	2.66	11.35	14.8	76.8	0.64
14	Fe 10 p. p. m.	3.22	11.50	14.3	80.4	0.53

See Table I for concentrations of elements in each treatment.

The best quality of the fruits is associated with the highest ratio of sugar content to total dissolved solids, and the lowest acidity in the juice.

The sugar content of the juice was lowest in the zinc, manganese and aluminum treatments. The treatment with no micronutrient elements added showed a low sugar content. The acidity was higher in these treatments. The copper treatment showed also some detrimental action, as shown by comparing treatment 5 with copper, and treatment 9 without copper. Iron and boron showed beneficial action for increasing the sugar content and lowering the acidity. Compare treatments 2 and 4 with 1.

The iron-manganese series showed low quality of juice in treatment 10, without iron. The other treatments, 11 to 14, showed increasing content of sugar and decreasing content of acid, with the increase in iron. Iron was the most important agent of high quality. All treatments with iron were superior to treatments without iron.

The reserve micronutrient elements in the slip were not sufficient to produce good quality, The values for treatment 1 showed rather low sugar content and a high acidity. Compare treatment 1 with treatment 8, which gave the best analysis next to number 14, that had 10 p.p.m. of iron. It seems that the chlorosis-producing effect of the elements is related to low sugar content, and high acidity.

V — SUMMARY AND CONCLUSIONS

A. *Work done*

Pineapple plants were grown in nutrient solutions from uniform and healthy slips used as the propagating organ. The solutions were prepared with a mixture of macronutrient elements containing ammonia and nitrate nitrogen, potassium, phosphorus, magnesium, calcium, and sulfur. The solutions proved to be good for the growth of pineapples.

Fourteen different treatments of the micronutrient elements: iron, manganese, boron, zinc, copper and aluminum, were used in triplicate. Combinations of these elements were made in order to trace their effect, either toxic or beneficial, on pineapple plant growth and production, on root growth, on flowering and fruiting, and on the quality of the fruit. The antidoting effect of iron against the chlorosis-producing action of manganese was also studied. Plants also were grown without adding micronutrient elements to the nutrient solution.

B. *Conclusions* (See footnote on page ~~237~~) 241

1. Iron antidotes the chlorosis-producing action of manganese in pineapple plants. With 5 parts per million of soluble manganese in a nutrient solution containing one-half part per million of boron, of zinc, and of aluminum, and 2 parts per million of copper, severe chlorosis and necrosis appeared before the pineapple plant was able to attain full growth. But, with one part per million of soluble iron humate added to a similar treatment, a healthy, normal plant was produced.

2. Iron counteracts the chlorosis-producing effect manifested by copper and boron. It raises their chlorosis-producing level.

3. Copper and manganese, at a concentration of 2 parts per million in the nutrient solution, produce strong chlorosis if iron is not present.

4. Aluminum and zinc show beneficial effects against chlorosis.

5. Iron shows no toxic effects on pineapple plants when added as the only micronutrient element to the culture solution, up to 5 parts per million. If chlorosis-producing elements like manganese or copper are present, higher concentrations are beneficial.

6. The reserve iron content in slips of the variety "Smooth Cayenne" is quite enough to counterbalance the detrimental chlorosis-producing effect of the other reserve micronutrient elements in the slip. However, plants grown in nutrient solutions deprived of all micronutrient elements produced fruits of lower sugar content than those supplied with micronutrient elements.

7. Pineapple plants respond to increase in iron in the nutrient solution, giving increase in green color, in yield, in sugar content and in decreased acid content. Treatments with a constant supply of manganese and other micronutrient elements, as explained above in (A), and with iron added in concentrations ranging from 1 to 10 parts per million, showed that the above-mentioned beneficial effect varied directly with the increase in iron added to the nutrient solution.

8. Iron prevents browning of root tips, or root rot, of pineapple plants under either anaerobic or aerobic conditions. Manganese and boron show also a somewhat beneficial action.

9. Copper has a highly beneficial action in preventing root-rot injury, when under anaerobic conditions. However, when the nutrient solution is well aerated the effect of copper is somewhat detrimental to the roots. Nonaerated solutions must be well supplied with copper and iron.

10. Aluminum has a beneficial action on root health and volume under the aerobic conditions of well aerated nutrient solutions, but it is highly toxic to the roots under anaerobic conditions.

11. Zinc exerts a somewhat detrimental action on roots under anaerobic conditions of the nutrient solution.

12. It seems that as far as root growth is concerned aeration plays an important role; copper having a beneficial action under anaerobic conditions; and aluminum when the nutrient solution is well aerated. Iron, manganese and boron are beneficial under any of the two conditions of oxygen supply.

13. Aluminum and manganese promote increased volume of roots when the nutrient solution is well aerated. Copper and zinc tend to reduce the volume of roots, but iron and boron show no direct effect.

14. Iron has a beneficial effect on early flowering and early maturity of the pineapple fruit.

15. Copper, zinc and boron, and the chlorosis-producing effect of manganese, have a retarding effect on flowering and fruiting. In

this action they are counteracted by iron. Aluminum shows no specific effect upon flowering and fruiting.

16. Zinc and copper tend to produce low yields. Aluminum and boron increase the yield. Manganese does not show specific effect on yield when added alone to the nutrient solution.

17. Zinc, copper, manganese and aluminum show a tendency to produce fruits with low sugar content and high acidity.

18. Iron and boron show a beneficial effect by increasing the sugar content and lowering the acidity. Iron is an important agent of high quality of pineapple fruits.

19. Zinc deficiency in the nutrient solution shows no signs of anatomical abnormalities in the pineapple plant.

20. Chlorosis in pineapple plants causes lower sugar content and higher ratios of acid to sugar in the fruit.

21. Experimentation on the mutual effect of the micronutrient elements on pineapple should take into consideration the reserve of elements in the planted slips.

22. The antidoting action of iron against the detrimental effects of copper should be studied by using varying concentrations of iron and different concentrations of copper.

23. Field experiments with iron humate added to the pineapple soils should be made to study its effect under soil conditions.

24. More available iron in soils will greatly improve the Puerto Rican pineapple crops.

NOTE: The above-mentioned conclusions on the independent action of the micronutrient elements refer to treatments in which they were added separately as the only micronutrient elements to the nutrient solutions in which the pineapple plants were grown. The concentrations used for each element were: 5 ppm Fe, 2 ppm Mn, 1 ppm B, 2 ppm Cu, 1 ppm Zn, and 1 ppm Al.

C. SYNOPSIS OF THE EFFECT PRODUCED BY MICRONUTRIENT ELEMENTS ON PINEAPPLE PLANTS, WHEN THE ELEMENTS ARE ADDED INDEPENDENTLY TO THE NUTRIENT SOLUTIONS

Element	PPM added to the nutrient solution	Chlorosis	Root-rot injury		Volume of roots aerated solutions	Production		
			Solutions					
			non-aerated	aerated		Early flowering and fruiting	Yields	Quality
Iron	5	Prevented Chlorosis	Prevented injury		No effect	Beneficial effect	High	High
Manganese	2	Severe Chlorosis	Beneficial effect against injury		Good	Retarding due to chlorosis	Not Specific	Low
Boron	1	Produced Chlorosis	Beneficial effect against injury		Not effect	Retarding effect	High	Good
Copper	2	Severe Chlorosis	Beneficial effect against injury	Detrimental effect	Detrimental effect	Retarding effect	Low	Low
Zinc	2	Prevented Chlorosis	Detrimental effect	No detrimental effect	Detrimental effect	Retarding effect	Low	Low
Aluminium	1	Prevented Chlorosis	Detrimental effect	Beneficial against injury	Beneficial effect	No effect	High	Low

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CALCIUM-BORON RELATIONSHIPS IN THE NUTRITION OF CORN AND THE DISTRIBUTION OF THESE ELEMENTS IN THE PLANTS

by **Ernesto Hernández-Medina** and **John W. Shive**

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CALCIUM-BORON RELATIONSHIPS IN THE NUTRITION OF CORN AND THE DISTRIBUTION OF THESE ELEMENTS IN THE PLANT [1]

ERNESTO HERNÁNDEZ-MEDINA [2] AND JOHN W. SHIVE [3]

The literature dealing with the inorganic nutrition of plants reveals that great attention has been given to the important role that the so-called trace elements play in the metabolic activities of different species of plants. Boron is one of these elements that has received particular attention in this regard. Both qualitative evidence and quantitative evidence (23, 28, 32, 33, 42, 43, 50) show that this element is indispensable for normal growth and development of plants and, therefore, it may be added to the previous list of essential elements (38).

Soils naturally low or deficient in boron have been reported (35, 48) in over half of the 48 states, with large areas occurring along the Atlantic coastal plain, in the Great Lakes region, and in the Pacific Northwest. If boron is not applied in usual fertilizer practices to such deficient or sub-deficient soils metabolic disturbances of the plants are likely to result in abnormal plant development as evidenced by the appearance of boron deficiency symptons and reduced crop production. Naftel (25,26,27) was one of several investigators (5,20,51) to show that liming of soils naturally low or deficient in boron is likely to cause an initiation or accentuation of boron deficiency symptoms in plants growing thereon. He found that in soils low or deficient in boron, liming decreased the water-soluble boron of the soil. On the other hand, White-Stevens (49) found that the effective level of boron in the fertilizer mixture for controlling boron deficiency in deficient soils depended upon the kind of crop grown. This suggests that care should be exercised in the application of fertilizer in soils lacking or low in boron.

The fact that it is virtually impossible (36,38) to distinguish externally between boron and calcium deficiency symptoms has sug-

[1] Rutgers University, Department of Plant Physiology, New Brunswick, New Jersey. Journal Series paper, New Jersey Agricultural Experiment Station. Part of a thesis submitted to the faculty of the Graduate School of Rutgers University in partial fulfillment of the requirements for the degree of Master of Science.

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gested a possible relation between these two elements in plant nutrition. Among the first investigators to suggest a possible association between boron and calcium in the plant were Brenchley and Warington (3,41) using the broad bean as an indicator plant. They suggested that boron either enables the plant to absorb more calcium in a given period of time or permits it to be used more efficiently once it is absorbed by the plant. In the absence of boron, calcium in the roots was not utilized effectively. Later work by Marsh and Shive with corn (17) corroborated the findings of Brenchley and Warington. They found that the presence of an appropriate amount of available boron in the plant tended to maintain, in an available condition, the calcium absorbed even if no additional calcium was supplied to the plant. Evidence is also presented which demonstrates that the boron content of the culture solution did not greatly influence rates of calcium absorption by the plants. In an annual report of the New Jersey Agricultural Experiment Station the suggestion is made that boron may influence the normal metabolism of calcium in plants (29). The suggestion is sustained by the fact that no calcium was found or detected in the cell sap in the meristems of boron deficient cotton plants. Results obtained by Lowenhaupt, working with sunflower (16), with reference to calcium content of tissues are in agreement with the view that there is a relationship between the boron available to the plant and the utilization of calcium. Haas (11) working with citrus and walnuts found no evidence in the leaves of any relationship between the soluble boron and the soluble calcium in the same tissues; while Muhr (24) working with sugar beets, radishes, chickory, turnip, barley, wheat, dandelions, mangels, rutabaga and corn, and Hill and Grant (12) with turnips found that tissue of plants inadequately supplied with boron contained, in general, a higher percentage of calcium than the tissue grown with sufficient boron. Still, there is a diversity of opinion among investigators as to the determinative role of boron in the accumulation of calcium in the plant. Haas (10) working with citrus found that the percentage of total calcium that was water soluble was higher in leaves of plants which received large quantities of boron in the substrate than in the leaves of plants receiving lower levels of boron in the nutrient medium. On the other hand, Holley and Dulin (13), Morris (22), and Dmitriev (7) furnished evidence to demonstrate that the presence or absence of boron in the nutrient media had no influence on the quantity of calcium in the plant tissue analyzed. As has been indicated (31) some disagreement may be due to the use of different species of plants, dif-

ferent growing media (sand and water cultures, in some cases, soil, in others) varying climatic conditions, and differences in the boron concentrations involved.

Later work (4,6,14) has furnished evidence that a definite balance exists between the calcium and boron content of healthy tomato, tobacco and oat plants. Brennan (4) has indicated that normal tomato plants have an intermediate numerical ratio of total calcium to total boron whereas boron deficient plants and boron toxic plants have abnormally high and abnormally low ratios, respectively.

The purpose of this investigation was to study further the calcium-boron relationship in the corn plant and to determine the distribution of these elements in this monocotyledon.

SERIES I

Methods

Cultural methods—This experiment was the first of two series and was started on October 16, 1945. The plants were grown in sand culture. Corn seeds of Rutgers Hybrid No. 2 were used. They were selected for uniformity in shape and size and were sowed directly in purified sand in 9 inch highly glazed pots. The sand was previously washed with tap water, then treated with 2 per cent sodium hydroxide and left overnight. Following this, it was flushed with distilled water, treated with 2 per cent hydrochloric acid and again left overnight, after which it was completely flushed with distilled water until free from chloride ions as determined by the silver nitrate test. This sand treatment was necessary to remove any materials which might furnish boron and also to free the sand from other nutrients. Four seeds were planted in each pot and the sand was flushed with a dilute nutrient solution of the following composition: KH_2PO_4, 0.0016 M.; $NaNO_3$, 0.0038 M.; $MgSO_4$, 0.0028 M.; $CaCl_2$, 0.0025 M. with the usual traces of iron, zinc and manganese but with no boron. Four days after germination the best three seedlings were left for treatment. The rejected seedling was removed by first flushing the sand with distilled water and then gently pulling it out with its entire root system. The cultures were maintained on the diluted culture solution for a week to develop uniform plants before nutrient treatments were started. At the end of this period all plants appeared vigorous and fairly uniform and the calcium-boron nutrient treatments were begun and maintained for 64 days, using the continuous solution renewal method of Shive and Stahl (39,40). Approximately two liters of nutrient solution per day were used for each culture containing three plants.

In this experiment there was a total of forty-eight cultures, which were divided into six groups of eight cultures each. Each group was grown at a different level of calcium, as follows: 5.0, 10.0, 50.0, 100.0, 250.0, and 500.0 p.p.m. Each of the eight cultures in a given calcium level received boron in eight different concentrations. The levels of boron used were as follows: 0.0, 0.001, 0.01, 0.10, 0.25, 5.0, 10.0, and 20.0 p.p.m. Figure 1 ilustrates the plan of the experiment the number on each block representing culture numbers. The composition of the culture solutions with the different levels of calcium used with each of the eight boron levels is presented in table 1. Salts of analytical grade were used without further repurification. Boron was supplied in the form of boric acid. The ammonium sulfate was used to aid in the prevention of iron-deficiency chlorosis.

At the end of the experimental period, on December 28, when definite symptoms of boron deficiency and toxicity occurred on plants receiving deficient and very high nutrient levels of boron respectively, the plants on the different treatments were harvested. After green and dry weights of the tops had been obtained, the plants were cut with a stainless steel knife into small pieces which were thoroughly mixed so that representative samples could be obtained for analysis.

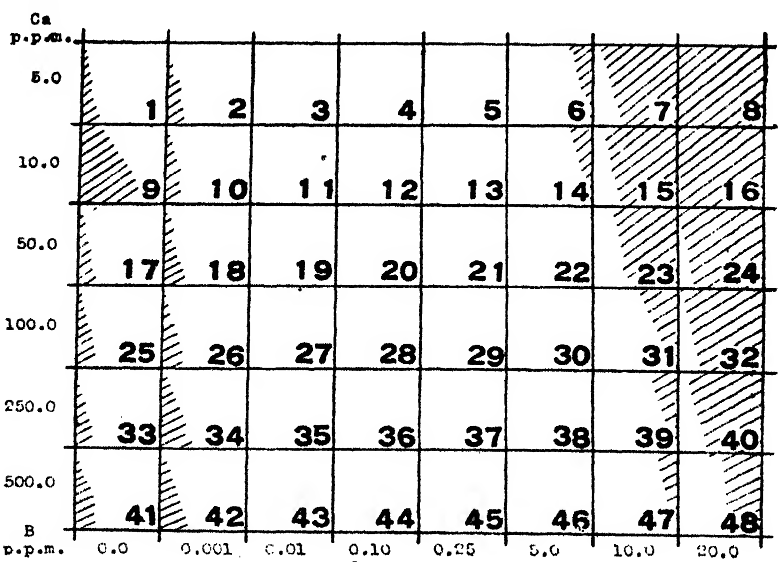

FIG. 1.—Diagram showing calcium and boron treatments and general experimental plan. Relative proportion of shaded area of each block at the left denotes relative degree of boron deficiency symptoms, those at the right boron toxicity symptoms.

TABLE NO. 1

COMPOSITION OF CULTURE SOLUTIONS AT EACH OF THE 6 DIFFERENT NUTRIENT LEVELS OF CALCIUM USED WITH EACH OF 8 DIFFERENT BORON CONCENTRATIONS OF 0.0, 0.001, 0.01, 0.10, 0.25, 5.0, 10.0, AND 20.0 P. P. M.*

Culture Numbers	Calcium Levels	Molar Concentration of Salts						
		KH_2PO_4	K_2SO_4	$NaNO_3$	$MgSO_4$	$CaCl_2$	$CaSO_4$	$(NH_4)_2SO_4$
	p. p. m.							
1-8	5	.00113	.00113	.0085	.00113	.000125	......	.0004
9-16	10	.00113	.00113	.0085	.00113	.00025	......	.0004
17-24	50	.00113	.00113	.0085	.00113	.00125	......	.0004
25-32	100	.00113	.00113	.0085	.00113	.0025	......	.0004
33-40	250	.00113	.00113	.0085	.00113	.00625	......	.0004
41-48	500	.00113	.00113	.0085	.00113	.00625	.00625	.0004

* TRACE ELEMENTS: Each nutrient solution contained 1 p. p. m. iron, 0.5 p. p. m. zinc, and 0.25 p. p. m. manganese used in the form of sulfates.

In order to determine the soluble boron and calcium in the plant tissue, a 50–gram sample of fresh tissue from each culture was frozen in a refrigerator immediately at time of harvest and kept at approximately minus 18°C until ready for analysis. In addition, 100–gram samples of fresh tissue were weighed and dried as described below to be used in the determinations for total boron and total calcium in each aliquot.

At the time of harvest one of the three plants from a culture receiving a high and a low boron level in each calcium series was harvested separately and fractionated into top leaves, middle stem and lower stem in order to make a preliminary study of the distribution of the total boron and calcium in these portions of the plant. The fraction designated as "top leaves" consisted of the leaves extending above and including the apical meristem; the "middle stem" fraction consisted of the culm tissue including leaf sheath but without blades extending from the base of the apical meristem to the node second removed from the sand surface; the "lower stem" fraction consisted of the lower two nodes and internodes of the culm including leaf sheaths but without blade tissue.

Chemical Methods—Dry weights of the 100–gram samples of green tissue taken for analysis at the time of harvest were obtained after oven drying at 70°C for 48 hours. The dried tissue was then ground in a semi-micro Wiley mill to pass a 40 mesh screen, after which 2–gram samples were weighed into porcelain crucibles and ignited in a muffle furnace starting at room temperature and gradually raising the temperature to 600°C. The samples were held at this temperature for approximately 6 hours which resulted in complete ashing. The ash was dissolved in 20 ml. of (1 +4) HCl, transferred

to a 100 ml. volumetric flask and made to volume. Aliquots of this solution were then taken for determination of total boron and total calcium.

For the determination of tissue contents of soluble boron and soluble calcium, the frozen 50-gram tissue samples were thawed and then placed in a piece of muslin of suitable size fitted in a nickel plated steel cylinder 5.71 centimeters inside diameter, covered with 40 ml. of distilled water, and subjected to a pressure of 2500 pounds per square inch for one minute in a Carver Press. The press cake was washed twice more with 40 ml. of distilled water and subjected to the same pressure but after the last washing the pressure was maintained for two minutes. The extracted plant juices and washings were passed through a quantitative Whatman number 5 filter paper using suction. The press cake was then removed from the muslin and together with the filter paper was oven-dried at 70°C for 48 hours. After drying, press cake and filter paper were ignited in a muffle furnace and the ash was dissolved and the solution made to volume as previously described. Aliquots of these samples were taken for the determinations of boron and calcium, respectively. Soluble boron and soluble calcium contents of the tissue were determined by the differences between the analytical values of these two elements in the unextracted sample and the extracted press cake.

In this work the soluble portions of boron and of calcium are considered to be those which were extracted from the tissue samples under pressure by the method described and these soluble portions are also considered to be the active portions in the tissue at least at the time of harvest. Those portions of the calcium and boron which remain in the plant tissue in the press cake after extraction of the juices by the above method are considered to be the insoluble and inactive portions.

The official micro-method of the Association of Official Agricultural Chemists (1) with a few minor changes was used for the calcium determinations. Since it is not necessary to remove the silicon dioxide, this step was omitted (21). Coprecipitation of the silicon dioxide with calcium oxalate does not interfere in the titration of the oxalate ions by the permanganate ions. To obtain greater accuracy in the results 0.01 N $KMnO_4$ was used for titrating the oxalate ion instead of 0.02 N solution recommended in the *official* method.

The Berger and Truog (2) colorimetric method was used for the quantitative determination of boron with modifications similar to those of Marsh and Shive (17) except that 10 ml. quantities of sul-

furic acid-quinalizarin reagent were used with 1 ml. of the test solutions instead of the 50 ml. quantities used by Marsh and Shive. The 50 ml Nessler tubes used for color comparison of standards and test solutions were kept tightly closed during the determinations. Sulfuric acid, 95.5 per cent by weight, was used in this method instead of the 98 per cent acid employed by Berger and Truog.

Results

Character of Plants after Treatment.—The relative intensities of the visible symptoms of metabolic disorder resulting respectively from deficient and excess nutrient concentrations of boron in the culture solution are represented by the shaded areas in figure 1. All the plants at the two lowest boron levels, 0.00 and 0.001 p.p.m. exhibited boron deficiency symptoms. However, as is indicated in figure 1, none of these boron deficient plants were very seriously injured and, moreover, no definite relation is observable between severity of boron deficient symptoms and relative calcium concentrations of the substrate. The injury due to boron deficiency which occurred in boron deficient cultures in this experiment ranged from slight to medium intensity and was not so severe as that in similar nutrient treatments in the experiment to be reported later in this paper. The boron deficiency symptoms were characterized by the appearance of elongated white transparent interveinal stripes on the newly formed leaves (44) and were similar but not quite so severe as those on leaves of plants shown in figure 2, which were grown in a subsequent experiment. The roots of the boron deficient plants were slightly brown, and the root systems were not so extensive as those of plants receiving boron. These symptoms were especially severe at the low calcium levels probably as a result of both boron and calcium deficiencies.

It has been reported (46) that under the short day conditions of spring and autumn the onset of boron deficiency symptoms is delayed as compared with long day conditions of summer. Since this experiment was run during the fall season it is possible that the short length of day may account for the fact that the boron deficiency symptoms were not so severe as those which developed in boron deficient cultures grown in the subsequent experiment conducted under the long day conditions of late spring. No distortion or injury was observed in apical meristems of boron deficient plants.

Figure 1 shows that slight boron toxicity symptoms appeared in cultures number 6 and number 14 receiving 5.0 p.p.m. boron at the two lowest calcium levels. Plants in other cultures grown at this boron level exhibited no toxicity symptoms. At the boron concentrations

of 10.0 p.p.m., boron toxicity symptoms were more severe than at 5.0 p.p.m. and appeared to some extent in plants at all calcium levels. At the boron level of 20.0 p.p.m. the metabolic disturbances due to the high boron concentration were most pronounced and were especially severe at the three lowest calcium levels.

The plants grown at 20.0 p.p.m. boron and with 5.0 p.p.m. of calcium (figure 3) showed more serious symptoms of boron toxicity than the plants grown at the same boron level but with 500.0 p.p.m. calcium (figure 4). Boron toxicity symptoms consisted of stunted

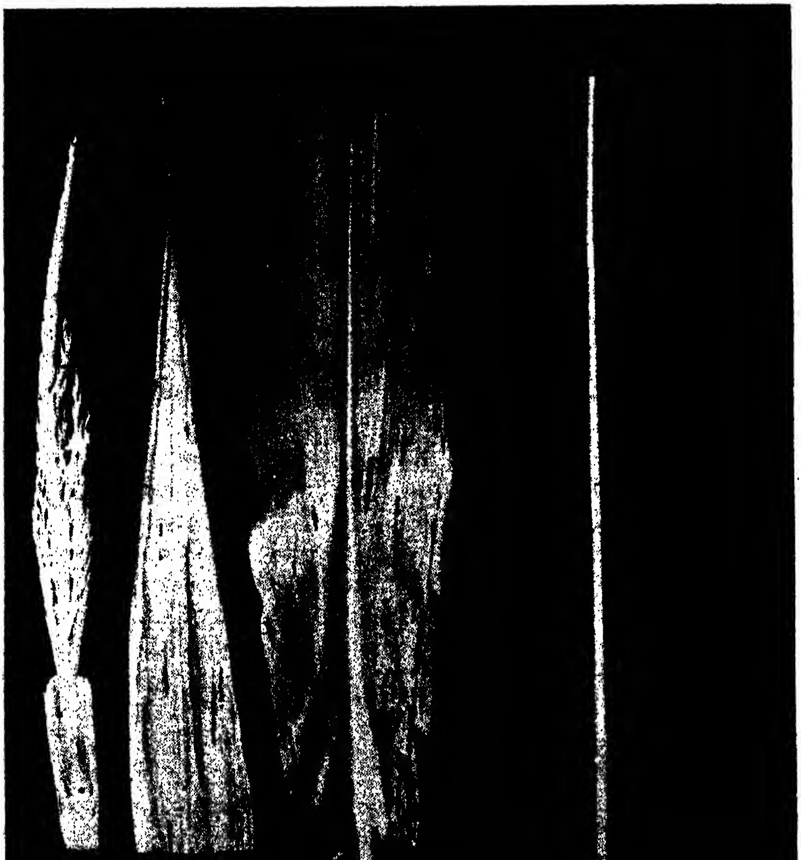

FIG. 2.—Typical boron deficiency symptoms of growing point and top leaves of corn plant grown at nutrient levels of 250.0 p.p.m. calcium and 0.001 p.p.m. boron.

growth, pale yellow-green color of the youngest leaves with yellow colored, dying and dead marginal tissue appearing largely on the older leaves. Typical boron toxicity symptoms are shown in figure 5 on the leaves of plants grown in a subsequent experiment. The root system of boron toxic plants were relatively small and the roots were brown in color. The appearance of these root systems was similar to those of plants receiving similar treatments and grown in a subsequent experiment.

Calcium deficiency symptoms were observed to some extent in the younger leaves of plants receiving 5.0 and 10.0 p.p.m. calcium. These symptoms consisted of distortions, breaks, and colorless areas

FIG. 3.—Corn plants grown in culture number 8 at nutrient levels of 5.0 p.p.m. calcium and 20.0 p.p.m. boron.

of tissue on the margins and tips of the leaves. These calcium deficiency symptoms are similar to, but not so serious as those which occurred on leaves of plants grown in a subsequent experiment. (Figure 6).

With regard to green and dry weights of the whole tops of the plants grown with the various calcium-boron nutrient levels it was found that with few exceptions green and dry weights increased as the calcium concentration of the substrate increased at any given boron level. The green and dry weights of the plants receiving the highest nutrient levels of boron 5.0, 10.0 and 20.0 p.p.m. within

FIG. 4.—Corn plants grown in culture number 48 at nutrient levels of 500.0 p.p.m. calcium and 20.0 p.p.m. boron showing mild symptoms of boron toxicity.

a given calcium level were considerably lower than the weights of those plants receiving lower nutrient levels of boron.

Results of Chemical Analyses.—The results of quantitative analyses for boron and calcium contents of the tissues, both total and soluble, are presented in table 2. It appears from the analytical data that both total boron and soluble boron at any given nutrient level of boron are more or less independent of the calcium concentration in

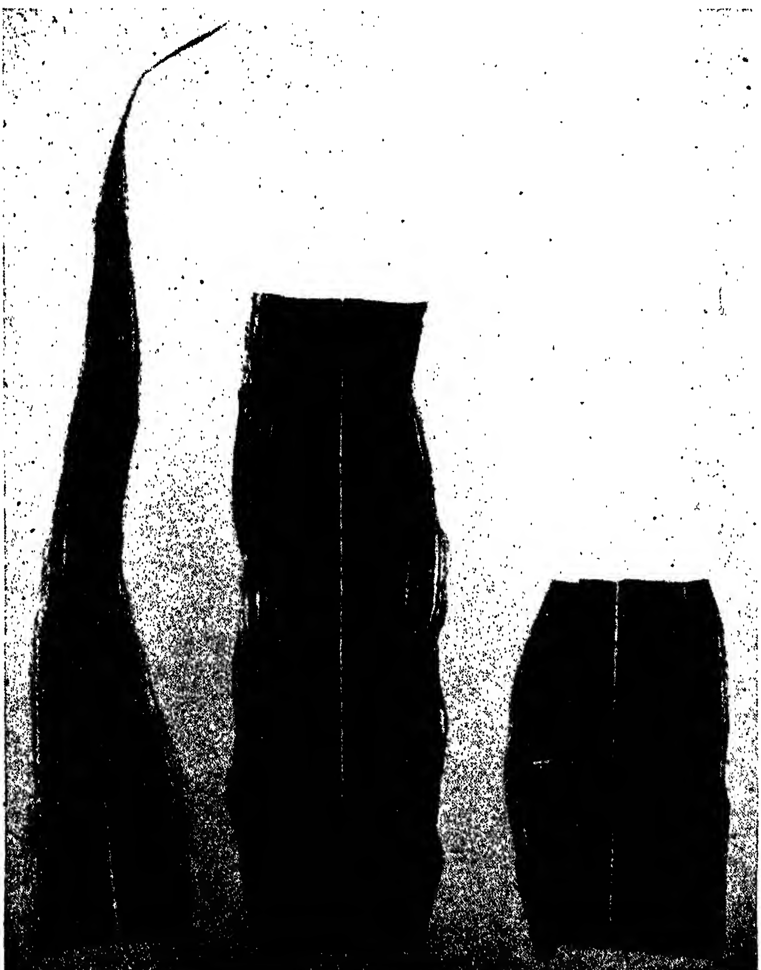

FIG. 5.—Typical boron toxicity symptoms of lower leaves of corn plant grown at nutrient levels of 100.0 p.p.m. calcium and 20.0 p.p.m. boron.

the substrate. However, the plants receiving highest nutrient concentrations of boron (20.0 p.p.m.) contained somewhat lower tissue contents of boron, both total and soluble, when grown at the highest calcium level (500.0 p.p.m.) than plants grown at equivalent boron level but at lower calcium concentrations. This suggests that boron accumulation by the plant was modified in some way at the highest calcium level. These results support the qualitative observations wherein boron toxicity symptoms of plants receiving the highest

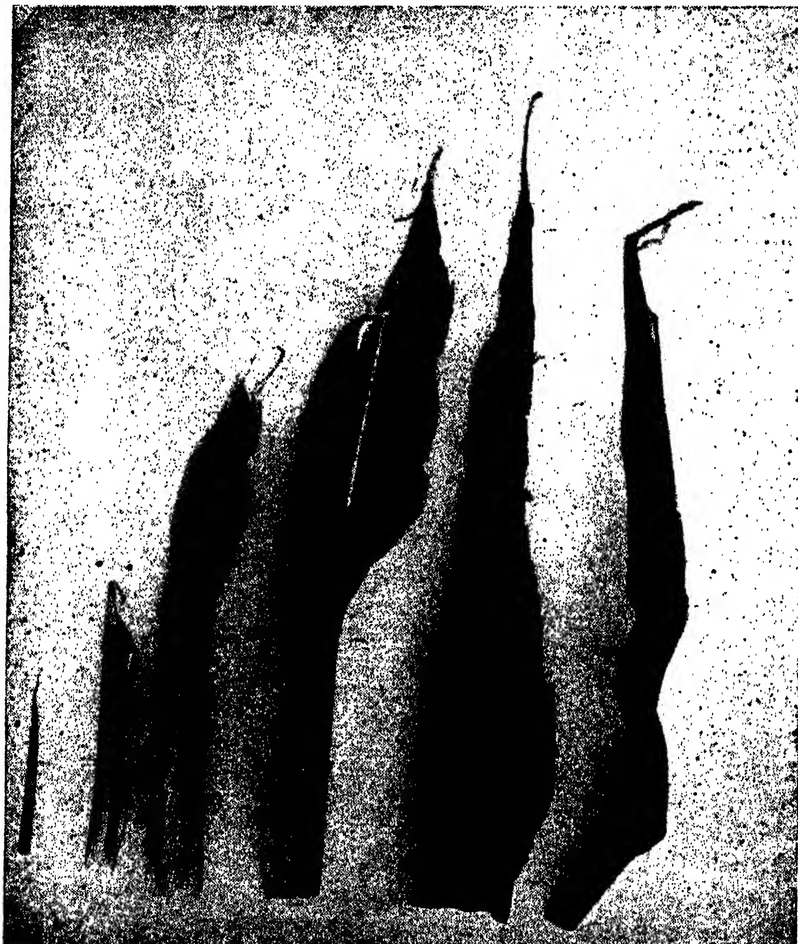

FIG. 6.—Leaves showing well defined calcium deficiency symptoms of corn plant grown at nutrient levels of 5.0 p.p.m. calcium and 0.25 p.p.m. boron.

TABLE No. 2

TOTAL AND SOLUBLE CALCIUM AND BORON IN MILLIGRAMS PER GRAM DRY TISSUE OF WHOLE TOPS OF CORN PLANTS OF SERIES I

Treatment Ca	Treatment B	Total B	Soluble B	Soluble B Per cent of Total	Total Ca	Soluble Ca
p. p. m.	p. p. m.	mgm. p. g.	mgm. p. g.	Per cent	mgm. p. g.	mgm. p. g.
5	0.0	0.010	0.002	20.0	0.84	0.53
5	0.001	0.015	0.007	46.6	1.08	0.56
5	0.01	0.020	0.008	40.0	0.95	0.63
5	0.10	0.023	0.012	52.1	1.14	0.77
5	0.25	0.030	0.016	53.3	1.36	1.00
5	5.0	0.300	0.206	68.8	1.00	0.51
5	10.0	0.450	0.388	86.2	1.18	0.85
5	20.0	0.750	0.567	74.6	0.91	0.54
10	0.0	0.010	0.002	20.0	1.63	1.10
10	0.001	0.015	0.006	40.0	1.41	0.84
10	0.01	0.020	0.009	45.0	1.25	0.71
10	0.10	0.023	0.015	65.2	1.51	1.06
10	0.25	0.030	0.016	53.3	1.94	1.24
10	5.0	0.174	0.059	33.9	1.57	1.17
10	10.0	0.424	0.266	62.7	1.65	1.13
10	20.0	0.997	0.610	61.1	1.58	1.02
50	0.0	0.020	0.008	40.0	3.69	2.12
50	0.001	0.020	0.009	45.0	3.11	1.97
50	0.01	0.025	0.013	52.0	3.10	2.02
50	0.10	0.030	0.017	56.6	4.00	2.30
50	0.25	0.031	0.019	61.2	3.09	1.27
50	5.0	0.175	0.119	68.0	3.53	2.61
50	10.0	0.424	0.358	84.4	3.75	2.09
50	20.0	0.765	0.557	72.2	4.59	2.76
100	0.0	0.015	0.008	53.3	5.18	3.22
100	0.001	0.015	0.009	60.0	4.93	2.34
100	0.01	0.025	0.015	60.0	4.75	2.75
100	0.10	0.032	0.019	59.3	4.78	2.88
100	0.25	0.040	0.024	60.0	4.72	3.93
100	5.0	0.250	0.204	80.0	5.62	3.75
100	10.0	0.449	0.384	85.5	4.65	3.25
100	20.0	0.750	0.574	76.5	6.72	4.25
250	0.0	0.015	0.008	53.3	5.80	4.11
250	0.001	0.015	0.007	46.6	6.78	5.40
250	0.01	0.025	0.015	60.0	6.08	4.50
250	0.10	0.035	0.021	60.0	5.93	4.47
250	0.25	0.035	0.018	51.6	5.73	4.13
250	5.0	0.137	0.087	63.5	5.93	4.46
250	10.0	0.350	0.289	82.5	5.73	4.34
250	20.0	0.750	0.531	70.8	8.03	6.01
500	0.0	0.015	0.007	46.6	6.64	5.14
500	0.001	0.015	0.007	46.6	6.70	5.50
500	0.01	0.020	0.012	66.0	6.61	4.95
500	0.10	0.030	0.015	50.0	7.37	5.77
500	0.25	0.030	0.021	70.0	6.33	5.07
500	5.0	0.128	0.093	72.6	7.12	5.74
500	10.0	0.424	0.241	56.8	6.60	5.07
500	20.0	0.624	0.428	68.6	7.93	6.26

nutrient level of boron (20.0 p.p.m.) were less severe at the highest calcium level (500.0 p.p.m.) than at lower calcium levels. These differences in severity of boron toxicity symptoms were also reflected in the green and dry weight yields of the plants. Parks et al working with tomatoes obtained reduced green and dry weights of plants receiving toxic quantities of boron (31).

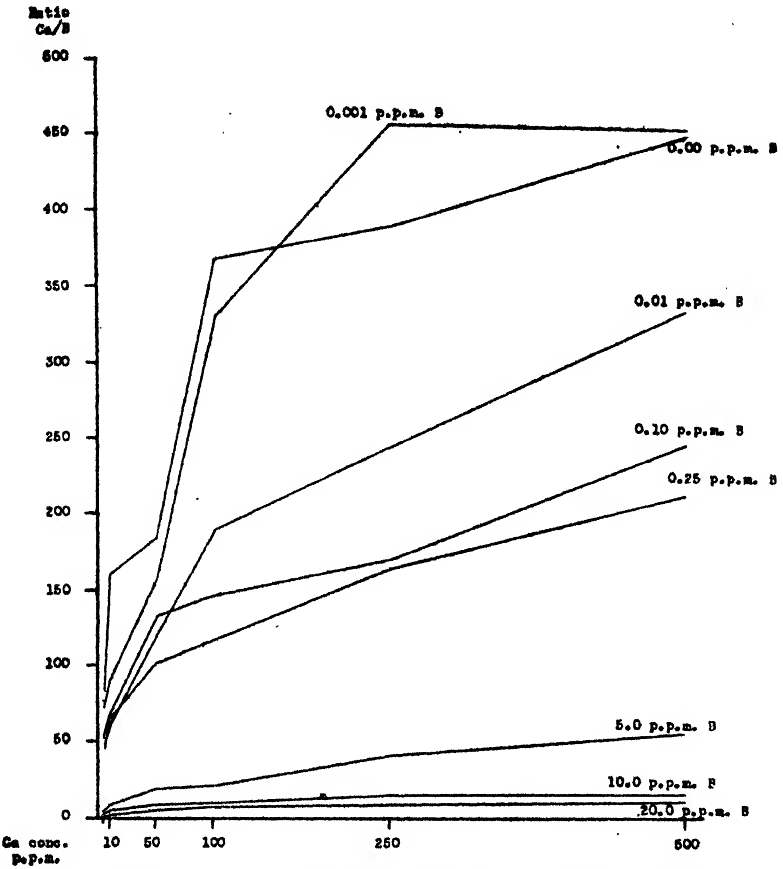

FIG. 7.—Ratios of total calcium to total boron of whole tops of corn plants grown at different boron levels plotted against calcium concentration in the substrate.

The experimental results also show that, in general, at each nutrient level of calcium a relatively higher percentage of the total boron remains soluble in the corn plant at the three highest boron levels than at the lower boron concentrations. This is similar to results obtained by Marsh with corn in which the lowest and highest percentage of soluble boron occurred at deficient and toxic boron substrate levels respectively (18).

Within any given calcium level the tissue contents of soluble boron were smaller in the plants grown at the two lowest boron levels than at the higher boron levels (table 2). Plants containing the lowest soluble boron at any given calcium level showed evidence of typical boron deficiency symptoms. This suggests that in this ex-

TABLE NO. 3

RATIOS OF DRY WEIGHT TISSUE CONTENTS OF TOTAL CALCIUM TO TOTAL BORON OF WHOLE TOPS OF CORN PLANTS OF SERIES I

Treatment		Total Ca / Total B	Treatment		Total Ca / Total B
Ca	B		Ca	B	
p. p. m.	p. p. m.		p. p.m.	p. p. m.	
5	0.0	84	100	0.0	368
5	0.001	72	100	0.001	331
5	0.01	48	100	0.01	191
5	0.10	51	100	0.10	148
5	0.25	45	100	0.25	118
5	5.0	3	100	5.0	22
5	10.0	25	100	10.0	10
5	20.0	1	100	20.0	9
10	0.0	183	250	0.0	389
10	0.001	92	250	0.001	455
10	0.01	63	250	0.01	244
10	0.10	67	250	0.10	170
10	0.25	64	250	0.25	164
10	5.0	9	250	5.0	43
10	10.0	4	250	10.0	16
10	20.0	1.6	250	20.0	11
50	0.0	185	500	0.0	416
50	0.001	156	500	0.001	449
50	0.01	120	500	0.01	323
50	0.10	134	500	0.10	216
50	0.25	104	500	0.25	217
50	5.0	20	500	5.0	56
50	10.0	9	500	10.0	16
50	20.0	6	500	20.0	13

periment a constant nutrient supply of boron ranging from 0.01 to 0.25 p.p.m. was required to allow corn plants to grow normally.

From the results with regard to total and soluble calcium presented in table 2, it is evident that total calcium content of the tissue is mainly determined by the calcium concentration in the substrate and is largely independent of the nutrient concentration of boron. At each of the three highest levels of calcium, plants grown with the highest boron treatment had a considerably higher total and soluble calcium content than plants grown with the other boron treatments. These differences appear large enough to have some significance but their determinative factors are not clear.

From the analytical data relating to calcium and boron contents of the plant, the ratios of total calcium to total boron for the plants grown at the different calcium and boron levels have been calculated and presented in table 3. In figure 7 are presented the same Ca/B ratios plotted against calcium concentrations of the substrate. It is evident from the ratios of table 3 that the tissue of boron deficient plants receiving nutrient treatments of 0.0 and 0.001 p.p.m. boron had the highest Ca/B ratios at any given nutrient level of calcium while the Ca/B ratios of the tissues of boron-toxic plants were the lowest. Tissues of normal plants receiving intermediate amounts of

boron had intermediate ratios. It appears from the results that the quantitative relationship between calcium and boron in the tissues greatly influences the metabolic activities of the corn plant. The qualitative observations made on the plants (figure 3 and 4) which exhibited symptoms of boron toxicity seem to be definitely associated with the calcium and boron contents of these plants. At 500.0 p.p.m. calcium and 20.0 p.p.m. boron, the boron toxicity symptons were considerably less severe than those of plants grown with the same nutrient level of boron but at lower calcium levels. They also had the highest Ca/B ratio, 13 to 1, while the plants grown at 5.0 p.p.m. calcium and 20.0 p.p.m. boron had a Ca/B ratio of only 1 to 1 (table 3.). Although the proportion of calcium to boron in the plants in the first case mentioned above (500.0 p.p.m., 20.0 p.p.m. boron) was probably not the optimum for normal plant metabolism, nevertheless it seemed to be associated in some way with less severe boron toxicity than was evident in the plants grown at the highest boron level at the lowest calcium concentration. These were the plants that had a very low Ca/B ratio (figure 3). It can also be seen from table 3 that as the boron increased at a given calcium level the Ca/B ratio decreased.

Results of Chemical Analyses of Tissue Fractions of Corn Plant Tops

The results of quantitative tests for total boron and total calcium of the tissue fractions of plants grown at low and high boron levels

TABLE NO. 4

TOTAL BORON AND TOTAL CALCIUM OF TOP LEAVES, MIDDLE STEM, AND LOWER STEM OF CORN PLANTS OF SERIES I EXPRESSED AS MILLIGRAMS PER GRAM DRY TISSUE

Treatment		Top Leaves		Middle Stem		Low Stem	
Ca	B	Total B	Total Ca	Total B	Total Ca	Total B	Total Ca
p. p. m.	p. p. m.	mgm. p. g.	mgm. p. g.	mgm. p. g.	mgm. p. g.	mgm. p. g.	mgm. p. g
5	0.001	0.025	0.63	0.020	1.43	0.020	0.65
5	5.0	0.180	0.43	0.325	0.92	0.080	0.58
10	0.01	0.025	1.10	0.025	1.98	0.020	0.94
10	5.0	0.175	0.89	0.275	1.76	0.080	0.82
50	0.01	0.030	2.19	0.025	5.02	0.020	2.41
50	5.0	0.175	2.83	0.275	3.52	0.100	1.65
100	0.10	0.035	3.04	0.035	4.97	0.030	2.89
100	5.0	0.199	2.70	0.225	5.19	0.080	3.94
250	0.01	0.030	5.39	0.030	8.46	0.010	6.18
250	5.0	0.325	5.16	0.250	7.31	0.070	5.94
500	0.001	0.030	4.23	0.020	6.41	0.010	6.28
500	5.0	0.275	4.39	0.300	10.16	0.080	8.25

(0.001, 0.01, 0.10 and 5.0 p.p.m.) at each of the six calcium concentrations are presented in table 4. These were the plants which were divided into top leaves, middle and lower stem fractions. As was pointed out before, this preliminary study was carried out to obtain an idea as to the distribution of the total calcium and boron in these three different portions of the corn plant. An analysis of the data shows that in general at the lowest boron level and at each nutrient level of calcium, boron is more or less equally distributed among top leaves, middle stem, and lower stem, with the least amount found in the lower stem tissue. However, at the highest boron level, and at each calcium level, the boron content of the middle stem was greater than that of the top leaves with but one exception, and the lower stems had the least amount of boron at this boron level.

It is also evident from the results presented in table 4 that the tissue content of calcium was greater in the middle stem portion of the plant at any given nutrient level of calcium. The amount of calcium found in each tissue was directly related to the calcium concentration in the substrate, with one exception, and was not greatly influenced by the boron concentration of the nutrient solution, with two exceptions. This occurred in the case of plants grown with the culture solution containing both 5.0 p.p.m. boron and 500.0 p.p.m. calcium where the calcium content of the middle and lower stem was considerably more than the calcium content of the respective tissue fractions of plants grown at 500.0 p.p.m. calcium but with only 0.001 p.p.m. boron.

Table 4 shows also that a relatively large amount of calcium accumulated in the lower stem of the plant at any given calcium level. But at the highest calcium levels (250.0, 500.0 p.p.m.) the lower stem had considerably greater tissue content of calcium than the top leaves. Thus it is evident that at these two highest calcium concentrations a large proportion of calcium accumulated in the lower or older part of the plant and was not freely translocated to the upper or younger leaves of the plant.

SERIES II

Methods

Cultural Methods.—The second corn series was started on April 18, 1946 to study the response of plants under different environmental conditions from those under which the first experiment was conducted. As before, seeds of Rutgers Hybrid No. 2 field corn selected for uniform size and shape were used in this test. Five

seeds were planted in each pot, and after germination the best three seedlings were left to receive treatments. During the first week of growth all corn cultures were supplied with the same dilute culture solution used during the first week with Series I. No boron was added during this period in order that the seedlings might utilize the supply of this element in the seed as far as possible before treatments were started. During the second week of growth all cultures received the same nutrient solution except that boron was added at the rate of 0.01 p.p.m. At the end of the second week all cultures were vigorous and appeared healthy in all respects.

The calcium-boron nutrient treatments were started beginning with the third week and were maintained for 30 days. Before applying treatments to plants, the sand in each culture was flushed with distilled water, then flushed again with the nutrient solutions to be used according to the experimental plan. As before, nutrient solutions were applied by the continuous solution renewal method. The culture solutions used with the different nutrient levels of calcium and of boron as well as the experimental setup were the same as in Series I. The calcium chloride salt used in the culture solutions of this series was purified by recrystallization after it was found by analysis to contain small amounts of boron. At the end of the experimental period of 30 days, plants were harvested. As before, green and dry weights of the tops were obtained and frozen samples of the plants of each culture were prepared for analysis. In addition, one of the three plants from a culture in each of the six different calcium levels and receiving 0.0, 0.25, and 20.0 p.p.m. boron respectively, was divided into four fractions—top leaves, top stems, lower leaves, and lower stems—for determinations of total and soluble boron and calcium of each tissue.

In the above tissue fractions the "top leaves" consisted of the apical meristem and the leaves arising in its immediate proximity and extending above it. The "top stems" consisted of the culm tissue starting downward from the base of the apical meristem and including the uppermost two differentiated internodes without attached blades and sheaths. The "lower leaves" consisted of all the leaves of the stem below the level of the apical meristem. The "lower stem" fraction consisted of the nodes and internodes below the base of the "top stems", as defined above.

Chemical Methods.—The same procedure and methods used in the first series were followed for the determination of total and soluble boron and calcium in the tissues of this corn series. Because

of the lack of sufficient plant material in some of the tissue fractions it was necessary in those cases to ignite a 1-gram instead of a 2-gram sample and to make to 50 ml. instead of 100 ml. volume.

RESULTS

Character of Plants after Treatments.—The relative intensities of the external symptoms of metabolic disturbance due to deficient and toxic quantities of boron in the nutrient media are represented by the proportion of the shaded areas in the blocks of the diagram of figure 8. If this diagram is compared with figure 1 a striking difference will be noted in the response of the plants to the low and high boron treatments at the various calcium concentrations. Symptoms of boron deficiency appeared first in the plants at the highest nutrient calcium concentrations, 19 days after treatment. At the end of the experimental period all plants at the two lowest boron levels of 0.0 and 0.001 p.p.m. showed boron deficiency symptoms, except those grown at the two lowest calcium levels. The boron deficiency symptoms increased in severity progressively as the calcium concentration of the substrate increased, except that somewhat more intense boron deficiency symptoms were detected at 250.0 p.p.m. calcium than at 500.0 p.p.m. calcium concentration.

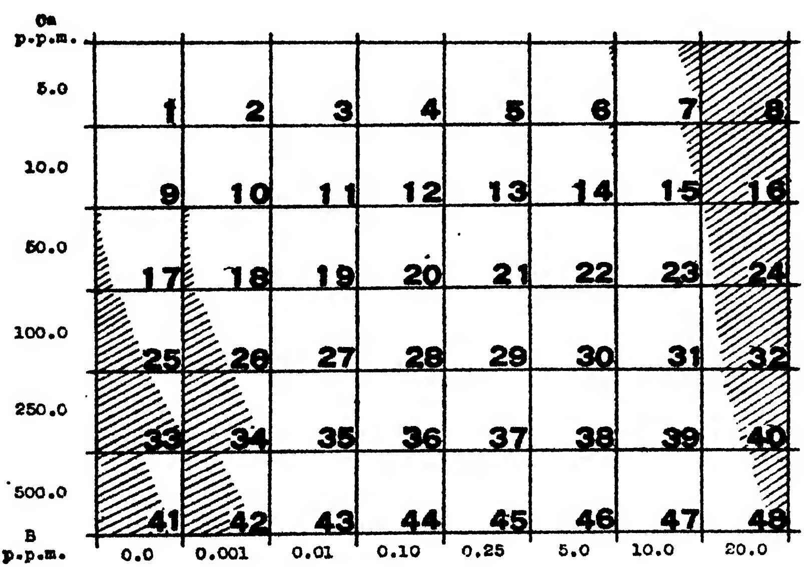

FIG. 8.—Diagram showing calcium and boron treatments and general experimental setup of Series II. Proportionate amounts of shading in the blocks indicate approximate relative severity of boron deficiency symptoms (left) and boron toxicity symptoms (right).

The growing points of boron deficient plants showed a brownish color as compared to the creamy-white color of growing points of healthy plants. The roots were brown and the root systems were less extensive than those of plants receiving adequate amounts of boron. As before, the boron deficiency symptoms of the roots were most severe at the low calcium levels. This was probably due to combination of both boron and calcium deficiency.

In this series, in contrast to the first series (figures 1, 8), there was virtually no indication of boron toxicity at 5.0 p.p.m. boron. With the exception of the plants at the two calcium levels of 5.0 and 10.0 p.p.m., where boron toxicity was only slight, the plants at other calcium levels did not show evidence of boron toxicity at 10.0 p.p.m. boron. However, as is evident from figure 8, injury due to boron toxicity occurred at 20.0 p.p.m. boron at all calcium levels but decreased in severity with increasing calcium concentration in the substrate. As in Series I, boron-toxic plants were characterized by a yellow-green color of the top leaves and by brown, dead margins and tips of the older or lower leaves. The roots of these plants were mostly brown and less abundant, especially at the two lowest calcium levels, as compared with the long, silvery-white and healthy roots of the plants receiving boron ranging between 0.01 to 0.25 p.p.m. Roots of plants receiving 5.0 and 10.0 p.p.m. boron showed slight boron injury as evidenced by their light brown color as compared with the silvery-white color of roots of plants supplied with lower concentrations of boron.

In the plants of this series the severity of calcium deficiency symptoms was considerably more pronounced in plants grown at 5.0 and 10.0 p.p.m. calcium than in the same treatments in Series I planted in the fall season. Plants were most severely injured at the lowest calcium level (5.0 p.p.m.) and were stunted considerably in vegetative growth (30). In some of the plants the young leaves failed to unroll properly and the tips of these cylinders of unrolled leaf tissue were dead or dying. The root systems of these calcium deficient plants were less extensive and were slightly browner than the roots of plants receiving larger amounts of calcium in the substrate. This probably indicates an early maturity of the tissues.

Results of Chemical Analyses.—The results of quantitative tests for total and soluble boron and calcium are presented in table 5. An examination of these data clearly demonstrates that the total and soluble boron in the corn plant is largely a direct function of the boron concentration in the substrate and is only slightly in-

TABLE No. 5

TOTAL AND SOLUBLE CALCIUM AND BORON IN MILLIGRAMS PER GRAM DRY TISSUE OF WHOLE TOPS OF CORN PLANTS OF SERIES II

Treatment		Total	Soluble	Soluble B	Total	Soluble
Ca	B	B	B	Per cent of Total	Ca	Ca
p. p. m.	p. p. m.	mgm. p. g.	mgm. p. g.	Per cent	mgm. p. g.	mgm. p. g.
5	0.0	0.020	0.007	30.0	0.61	0.30
5	0.001	0.030	0.013	43.3	0.72	0.30
5	0.01	0.040	0.022	55.0	0.61	0.31
5	0.10	0.045	0.026	57.7	0.78	0.39
5	0.25	0.045	0.025	55.5	0.66	0.25
5	5.0	0.175	0.132	75.3	0.63	0.31
5	10.0	0.424	0.358	84.7	0.69	0.22
5	20.0	0.624	0.529	84.7	0.54	0.18
10	0.0	0.020	0.006	20.0	0.97	0.55
10	0.001	0.025	0.013	52.0	0.81	0.51
10	0.01	0.030	0.015	53.3	0.86	0.53
10	0.10	0.035	0.023	65.7	0.92	0.58
10	0.25	0.035	0.025	71.4	0.92	0.42
10	5.0	0.175	0.147	84.0	0.78	0.39
10	10.0	0.325	0.265	81.5	0.88	0.54
10	20.0	0.625	0.536	85.7	0.77	0.45
50	0.0	0.025	0.011	44.4	2.87	1.96
50	0.001	0.025	0.013	52.0	2.33	1.62
50	0.01	0.030	0.017	56.6	2.64	1.72
50	0.10	0.035	0.023	65.7	2.58	1.83
50	0.25	0.040	0.025	62.5	2.11	1.24
50	5.0	0.137	0.119	86.8	2.31	1.80
50	10.0	0.325	0.288	88.8	2.56	1.96
50	20.0	0.625	0.526	76.4	2.36	1.31
100	0.0	0.020	0.009	45.0	4.49	3.33
100	0.001	0.020	0.010	50.0	4.33	3.19
100	0.01	0.025	0.012	48.0	3.69	2.78
100	0.10	0.029	0.020	68.9	3.39	2.15
100	0.25	0.040	0.022	55.0	4.09	3.18
100	5.0	0.137	0.102	74.4	3.77	2.52
100	10.0	0.325	0.267	82.1	4.36	3.37
100	20.0	0.749	0.650	86.7	4.42	3.26
250	0.0	0.020	0.009	45.0	5.39	2.76
250	0.001	0.025	0.012	40.0	5.06	3.36
250	0.01	0.025	0.015	60.0	4.82	3.49
250	0.10	0.030	0.019	63.3	3.95	3.04
250	0.25	0.040	0.022	55.0	4.97	3.70
250	5.0	0.137	0.111	81.0	4.70	3.40
250	10.0	0.325	0.263	80.9	5.60	4.32
250	20.0	0.750	0.608	81.0	5.11	3.58
500	0.0	0.025	0.010	40.0	5.56	4.62
500	0.001	0.025	0.010	40.0	5.27	3.84
500	0.01	0.030	0.019	63.3	5.76	3.38
500	0.10	0.040	0.021	52.5	6.07	3.38
500	0.25	0.040	0.025	62.5	5.15	4.04
500	5.0	0.175	0.139	79.4	5.59	3.92
500	10.0	0.325	0.255	78.4	5.55	4.13
600	20.0	0.625	0.447	71.5	9.25	5.84

fluenced by the calcium level. It is also evident from table 5 that, as was found in Series I, the soluble boron within the plant was somewhat less at the highest calcium level (500.0 p.p.m.) than at all of the lower nutrient levels of calcium. As in the first series, the data also show that in most cases a relatively higher percentage of the total boron remains soluble in the corn plant at the high boron levels than at lower nutrient levels of boron. However, the data fail to explain the qualitative observations made earlier with

TABLE No. 6

RATIOS OF DRY WEIGHT TISSUE CONTENTS OF TOTAL CALCIUM TO TOTAL BORON OF WHOLE TOPS OF CORN PLANTS OF SERIES II

Treatment		Total Ca / Total B	Treatment		Total Ca / Total B
Ca	B		Ca	B	
p. p. m.	p. p. m.		p. p. m.	p. p. m.	
5	0.0	31	100	0.0	226
5	0.001	24	100	0.001	218
5	0.01	15	100	0.01	148
5	0.10	17	100	0.10	119
5	0.25	15	100	0.25	103
5	5.0	3	100	5.0	27
5	10.0	2	100	10.0	13
5	20.0	0.9	100	20.0	6
10	0.0	40	250	0.0	271
10	0.001	33	250	0.001	203
10	0.01	29	250	0.01	194
10	0.10	26	250	0.10	132
10	0.25	26	250	0.25	125
10	5.0	4	250	5.0	34
10	10.0	3	250	10.0	17
10	20.0	1	250	20.0	7
50	0.0	115	500	0.0	223
50	0.001	94	500	0.001	212
50	0.01	88	500	0.01	193
50	0.10	74	500	0.10	152
50	0.25	53	500	0.25	129
50	5.0	17	500	5.0	32
50	10.0	8	500	10.0	17
50	20.0	6	500	20.0	15

regard to boron deficiency, that is, that this injury is intensified with increasing concentrations of calcium in the substrate, nor does it satisfactorily explain why boron toxicity decreased with increasing concentrations of calcium in the substrate. In tomato plants (4,37), the qualitative observations are in agreement with the quantitative data with regard to boron deficient and boron toxic plants. An explanation for this lack of agreement in the corn plant will be given later when the quantitative relationship between calcium and boron in the plant is considered, together with the analytical data with respect to total and soluble boron of the fractionated portions of the plant.

From the results presented with regard to total and soluble calcium of the plant, it is evident that the same trend follows as with the results obtained for the first series, that is, that the calcium content in the tissues is largely determined by the calcium concentration of the growth medium and is not greatly influenced by boron, with one principal exception, namely, in the case of plants grown at 500.0 p.p.m. calcium and 20.0 p.p.m. boron where total and soluble calcium content was much higher as compared with that of plants grown at the same calcium level but different boron concentrations. With the exception mentioned above, similar results were obtained

TABLE No. 7

TOTAL AND SOLUBLE BORON AND CALCIUM IN MILLIGRAMS PER GRAM DRY TISSUE OF *TOP LEAVES* OF CORN PLANTS OF SERIES II

Treatment		Total	Soluble	Total	Soluble
Ca	B	B	B	Ca	Ca
p. p. m.	p. p. m.	mgm. p. g.	mgm. p. g.	mgm. p. g.	mgm. p. g.
5	0.0	0.040	0.014	0.22	0.003
10	0.0	0.025	0.012	0.76	0.04
50	0.0	0.022	0.012	1.33	0.38
100	0.0	0.025	0.005	2.47	0.58
250	0.0	0.012	0.001	3.04	2.17
500	0.0	0.019	0.004	4.46	2.87
5	0.25	0.044	0.030	0.52	0.03
10	0.25	0.044	0.028	0.78	0.37
50	0.25	0.045	0.028	2.45	1.62
100	0.25	0.045	0.026	4.04	2.82
250	0.25	0.045	0.028	3.81	2.06
500	0.25	0.045	0.031	3.05	1.85
5	20.0	0.624	0.437	0.25	0.09
10	20.0	0.624	0.391	0.56	0.27
50	20.0	0.624	0.295	1.85	0.95
100	20.0	0.874	0.727	2.33	1.38
250	20.0	0.874	0.696	2.95	1.74
500	20.0	0.873	0.743	4.02	2.45

by Warington working with *Vicia faba* (47), Reeve (36), Brennan (4) working with tomato, and Reeve and Shive (37) working with both corn and tomato plants.

Again the ratios of total calcium to total boron in the plants were calculated and are presented in table 6. As in Series I, somewhat similar differences in ratios were obtained. It is evident from table 6 that, in general, at a given boron level as the calcium concentration in the substrate increase, the ratio of Ca/B increases also, while at a given calcium level as the boron in the substrate increases, the ratio decreases. Plants showing boron deficient symptoms had rather high Ca/B ratios especially at the higher calcium concentrations in the substrate, whereas plants with relatively intense boron-toxic symptoms had a very low ratio at the low calcium concentrations as compared with the intermediate ratios of healthy plants. As with the first corn series, the ratios presented indicate that a certain balance must exist between the calcium and boron content of the corn tissue to fulfill the requirements of healthy individuals. The fact that boron deficient and boron toxic plants had a high and low Ca/B ratio, respectively, points to the importance of the relationship between these two elements within the plant. The data of table 6 show that at the highest boron level (20.0 p.p.m.) as the calcium concentration of the substrate was increased the Ca/B ratio increased, as was to be expected, and is considerably higher at the last four calcium levels (50.0, 100.0, 250.0, 500.0 p.p.m. calcium) than at the first two calcium levels, respectively, (5.0,

TABLE No. 8

TOTAL AND SOLUBLE BORON AND CALCIUM IN MILLIGRAMS PER GRAM DRY TISSUE OF *LOW LEAVES* OF CORN PLANTS OF SERIES II

Treatment		Total	Soluble	Total	Soluble
Ca	B	B	B	Ca	Ca
p. p. m.	p. p. m.	mgm. p. g.	mgm. p. g.	mgm. p. g.	mgm. p. g.
5	0.0	0.030	.005	1.16	0.48
10	0.0	0.025	.015	1.43	0.62
50	0.0	0.025	.014	3.80	1.63
100	0.0	0.025	.008	4.83	3.01
250	0.0	0.022	.012	7.61	5.24
500	0.0	0.040	.023	9.13	6.88
5	0.25	0.056	.037	0.96	0.61
10	0.25	0.044	.025	1.35	0.55
50	0.25	0.045	.025	4.59	3.41
100	0.25	0.015	.027	5.48	4.03
250	0.25	0.045	.028	8.72	6.25
500	0.25	0.015	.028	7.77	5.81
5	20.0	1.750	1.585	0.91	0.52
10	20.0	0.874	.737	0.88	0.49
50	20.0	0.874	.455	4.01	2.46
100	20.0	1.130	.970	4.67	3.32
250	20.0	1.500	1.342	7.52	5.73
500	20.0	1.500	1.335	10.33	8.12

10.0 p.p.m. calcium). It was at these last four calcium concentrations that the plants showed a decrease in the intensity of injury due to boron toxicity, as can be observed in figure 8. The less toxic boron plants had a Ca/B ratio of 7 and 15 respectively as compared with ratios of 0.9 and 1 respectively of those plants showing much more boron toxicity. Thus it is apparent that there seems to exist a direct association between the appearance of boron deficiency and toxicity symptoms in the corn plant and the quantitative relationships of calcium and boron within the plant.

Results of Chemical Analyses of Tissue Fractions.—The analytical results of quantitative tests for total and soluble boron and total and soluble calcium of the tissues of the fractionated plants are presented in tables 7, 8, 9, and 10. The results obtained bring out several interesting points with regard to total and soluble boron content of the various tissues at the different boron levels. The tables show that, in general, at the lowest boron concentration of the substrate there was a greater accumulation of total and soluble boron in the older tissues of the plant (top stems, low stems, and low leaves) than in the top leaves and these differences were particularly marked at the highest nutrient levels of calcium. At the lowest nutrient level of boron the soluble boron contents of the top leaves at the three highest calcium levels (100.0, 250.0, and 500.0 p.p.m.) are relatively low as compared with the values at the three lower calcium levels. These data are in agreement with the qualita-

TABLE No. 9

TOTAL AND SOLUBLE BORON AND CALCIUM IN MILLIGRAMS PER GRAM DRY TISSUE OF *TOP STEMS* OF CORN OF SERIES II

Treatment Ca	Treatment B	Total B	Soluble B	Total Ca	Soluble Ca
p. p. m.	p. p. m.	mgm. p. g.	mgm. p. g.	mgm. p. g.	mgm. p. g.
5	0.0	....	....	....	....
10	0.0	0.030	0.011	0.75	0.41
50	0.0	0.030	0.013	1.42	0.99
100	0.0	0.030	0.009	1.78	1.13
250	0.0	0.040	0.017	2.93	1.88
500	0.0	0.050	0.016	3.51	2.59
5	0.25	0.070	0.023	0.44	0.17
10	0.25	0.015	0.027	0.50	0.26
50	0.25	0.030	0.012	1.31	0.85
100	0.25	0.040	0.013	2.00	1.36
250	0.25	0.010	0.015	2.45	1.68
500	0.25	0.050	0.019	4.55	1.64
5	20.0	0.125	0.087	0.26	0.01
10	20.0	0.350	0.307	0.56	0.11
50	20.0	0.299	0.261	1.89	1.32
100	20.0	0.225	0.202	2.73	1.96
250	20.0	0.274	0.218	7.01	5.50
500	20.0	0.225	0.178	6.44	4.99

tive observations made at the time of harvest, when it was noted that the boron-deficiency symptoms of the top leaves of the corn plant were most severe at the three highest calcium levels. However, it should be mentioned that the boron deficient injury was more pronounced in the plants supplied with 250.0 p.p.m. calcium than at either of the other two highest calcium levels. Thus, it is evident, that symptoms of boron deficiency are associated with the presence of small amounts of boron in the top portions of boron deficient plants as compared with plants receiving adequate amounts of boron (9). It appears from the results presented that at low boron concentration, a large proportion of boron accumulates in the older tissues of the plants and is not freely translocated to the top leaves where synthetic activity is highest. The fact that a large part of the total and soluble boron in plants to which boron was not intentionally supplied accumulated in the lower or older tissues instead of in the top leaves was probably responsible for the lack of agreement between the qualitative observations of boron deficient plants made at the time of harvest and quantitative results of the same plants when a composite sample of the whole top was analyzed for total and soluble boron. Unquestionably the low total and soluble boron content of the top leaves was masked by the presence of tissues containing high total and soluble boron (top stems, low leaves, and low stems) in the composite sample and, therefore, the qualitative observations of the boron deficient plants were not confirmed by quantitative analysis of whole tops. This indicates that the values

TABLE No. 10

TOTAL AND SOLUBLE BORON AND CALCIUM IN MILLIGRAMS PER GRAM DRY TISSUE OF *LOW STEMS* OF CORN PLANTS OF SERIES II

Treatment		Total	Soluble	Total	Soluble
Ca	B	B	B	Ca	Ca
p. p. m.	p. p. m.	mgm. p. g.	mgm. p. g.	mgm. p. g.	mgm. p. g.
5	0.0	0.020	0.004	0.29	0.13
10	0.0	0.045	0.017	0.54	0.30
50	0.0	0.045	0.030	1.26	0.89
100	0.0	0.020	0.008	3.36	2.86
250	0.0	0.030	0.013	4.05	3.22
500	0.0	0.040	0.012	6.86	5.58
5	0.25	0.022	0.008	0.28	0.15
10	0.25	0.022	0.008	0.35	0.21
50	0.25	0.034	0.014	1.56	1.19
100	0.25	0.045	0.024	2.88	2.29
250	0.25	0.045	0.020	3.46	2.66
500	0.25	0.040	0.016	5.54	4.20
5	20.0	0.175	0.161	0.29	0.03
10	20.0	0.350	0.313	0.34	0.15
50	20.0	0.349	0.309	2.01	1.46
100	20.0	0.274	0.246	2.41	1.92
250	20.0	0.349	0.304	6.99	5.97
500	20.0	0.350	0.302	13.33	11.29

of total and soluble boron contents of boron deficient plants as a whole do not provide reliable criteria of the concentration present in any given tissue.

The plants of the cultures supplied with 0.25 p.p.m. boron showed a much more equal distribution of this element throughout the various tissues than plants supplied with no boron or with very high nutrient levels of this element. At the nutrient level of 0.25 p.p.m. boron there was relatively little variation in the total boron contents of any given tissue fraction of plants grown with different calcium levels. At the same nutrient level of boron (0.25 p.p.m.) the soluble boron was higher in the top leaves and lower leaves than in the top and lower stems of the plants at any given calcium level, except in one case. This might be expected, since the leaves are more active than the stems in metabolic processes in which boron must take part.

The analytical data for total and soluble boron of all the cultures supplied with 20.0 p.p.m. boron show that the distribution of boron in the plant followed a definite course (19). The greatest amount of total and soluble boron accumulated in the lower leaves, while a considerably lesser amount was found in the top leaves. Low stems had a higher boron content than top stems. The qualitative observations made in regard to boron toxicity symptoms of plants grown at the highest boron level are in agreement with the quantitative data

TABLE NO. 11

RATIOS OF DRY WEIGHT TISSUE CONTENTS OF TOTAL CALCIUM TO TOTAL BORON IN THE VARIOUS FRACTIONS OF THE CORN PLANTS OF SERIES II

Treatment		Top Leaves	Low Leaves	Top Stems	Low Stems
Ca	B	Total Ca / Total B	Total Ca / Total B	Total Ca / Total B	Total Ca / Total B
p. p. m.	p. p. m.				
5	0.0	5	38	....	15
10	0.0	31	57	25	12
50	0.0	59	153	47	28
100	0.0	99	194	60	169
250	0.0	245	340	73	135
500	0.0	221	229	70	172
5	0.25	12	17	9	13
10	0.25	18	31	11	16
50	0.25	55	102	45	46
100	0.25	90	123	50	65
250	0.25	85	194	62	77
500	0.25	68	173	91	139
5	20.0	0.4	0.5	2	2
10	20.0	0.9	0.7	2	1
50	20.0	3.0	5.0	6	6
100	20.0	3.0	4.0	12	9
250	20.0	3.0	5.0	26	20
500	20.0	5.0	7.0	29	38

presented. The higher concentration of boron in the lower leaves paralleled the presence of boron toxic effects as evidenced by the brown and dead margins and tips of the lower leaves of the plants. Similar results were obtained by Eaton (8) and Purvis (34) due to a great accumulation of boron in the lower leaves of the plants.

The data further show that the total and soluble boron content of the various tissues depended largely upon the boron concentration of the substrate. However, in some cases the relative calcium concentration of the substrate modified the accumulation of this element within the plant at a given boron level, the greatest modification occurring at the highest boron level. As a general rule, the leaves were more sensitive to boron changes in the substrate than were either the top or low stems. Parks, Lyons, and Hood (31) reported that as boron supply in the substrate increased, the concentration of boron in the leaves increased significantly.

Calcium Content of Plant Tissues.—The analytical evidence gathered with reference to the calcium content of the various tissues of the corn plant shows that its distribution is regular and definite. The greatest amount of total and soluble calcium was found in the leaves of the plant, the lower leaves having the largest amount of this element (45). In general, the lower stems had a much higher calcium content than the top stems. The fact that much more total

and soluble calcium was found in the lower leaves and lower stems suggests that most of it was tied up in this lower portion of the plant and, therefore, was not freely translocated to the younger tissue where meristematic activity is highest. As a result of this condition the severe calcium deficiency symptoms of the cultures grown at 5.0 p.p.m. calcium and less marked deficiency symptoms at 10.0 p.p.m. calcium can be explained. It is interesting to note from table 7 that the top leaves of those plants grown at these two lowest calcium levels without boron contained considerably less soluble calcium than the top leaves of those plants grown at the same calcium levels but having boron in the substrate. The total calcium of the top leaves of the calcium deficient plants (5.0, 10.0 p.p.m. calcium) receiving no boron and 20.0 p.p.m. boron respectively at each of the two lowest calcium levels are comparable. There were only little differences between the total calcium contents of the top leaves of the plants grown at the lowest boron level (0.0 p.p.m.) and the

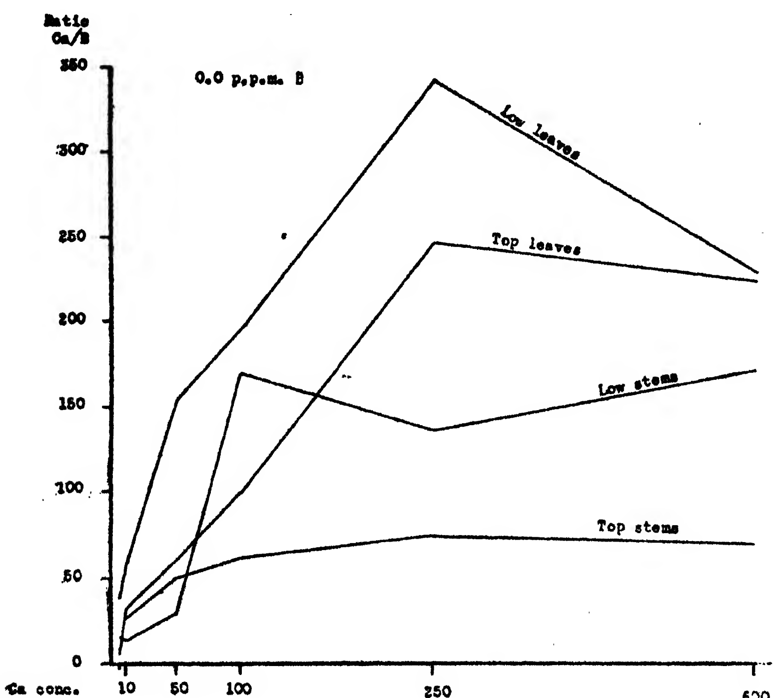

FIG. 9.—Ratios of total calcium to total boron in each fraction of corn plants grown at 0.0 p.p.m. boron plotted against calcium concentration in the substrate.

highest boron level (20.0 p.p.m.) at either of the two lowest nutrient levels of calcium respectively (5.0, 10.0 p.p.m.). This, however, was not true in the case of the soluble calcium content of these same tissues; the soluble calcium content being considerably greater in the calcium deficient plants grown at the highest boron level. These differences may be associated with the soluble boron content of the tissues of these calcium deficient plants. Where the soluble calcium content of the tissue was greatest, it was found that the soluble boron content was also the greatest. In other words, the soluble calcium in the top leaves of these calcium deficient plants is not so much a function of the total calcium as it is of the soluble boron. This relation described above did not hold true in the case of the other plant fractions. The same relation between the tissue content of soluble calcium and soluble boron has been obtained by Marsh and Shive (17) for whole tops of calcium deficient corn plants, by Lowenhaupt with the sunflower (16), and by Lorenz with garden beet (15). In general, at a given boron level as the calcium concentration of the substrate increased, there resulted an increased accumulation of total and soluble calcium in each of the various fractionated portions of the plant (47). In general, at a given calcium level, variations in the boron concentrations of the substrate did not influence greatly the calcium content of the tissue of the various plant fractions, except at the two highest calcium levels in the case of the top stems and lower stems where the values of total and soluble calcium were very high at the highest boron level.

From the analytical data pertaining to the calcium and boron content of the various tissues of the plants grown at various nutrient treatments, the Ca/B ratios were calculated in a manner similar to that previously used to determine Ca/B ratios for the whole tops. These ratios are presented in table 11. It is evident that plants showing boron deficient symptoms had the highest Ca/B ratios in the various fractionated portions while those giving evidence of boron toxicity and calcium deficiency had very low Ca/B ratios. On the other hand, the plants which did not show any injury and which were apparently healthy had intermediate ratios. The plants which had the greatest green and dry weights, those supplied with 250.0 p.p.m. calcium and 0.25 p.p.m. boron, and which were in all respects healthy, had a ratio of Ca/B of 125 as calculated from the composite sample of the whole tops (table 6). The Ca/B ratios of the individual tissue fractions of the plants grown with the same nutrient treatments were as follows: top leaves 85; low leaves 194; top stem 62; and low stem 77 (table 11). As was to be expected,

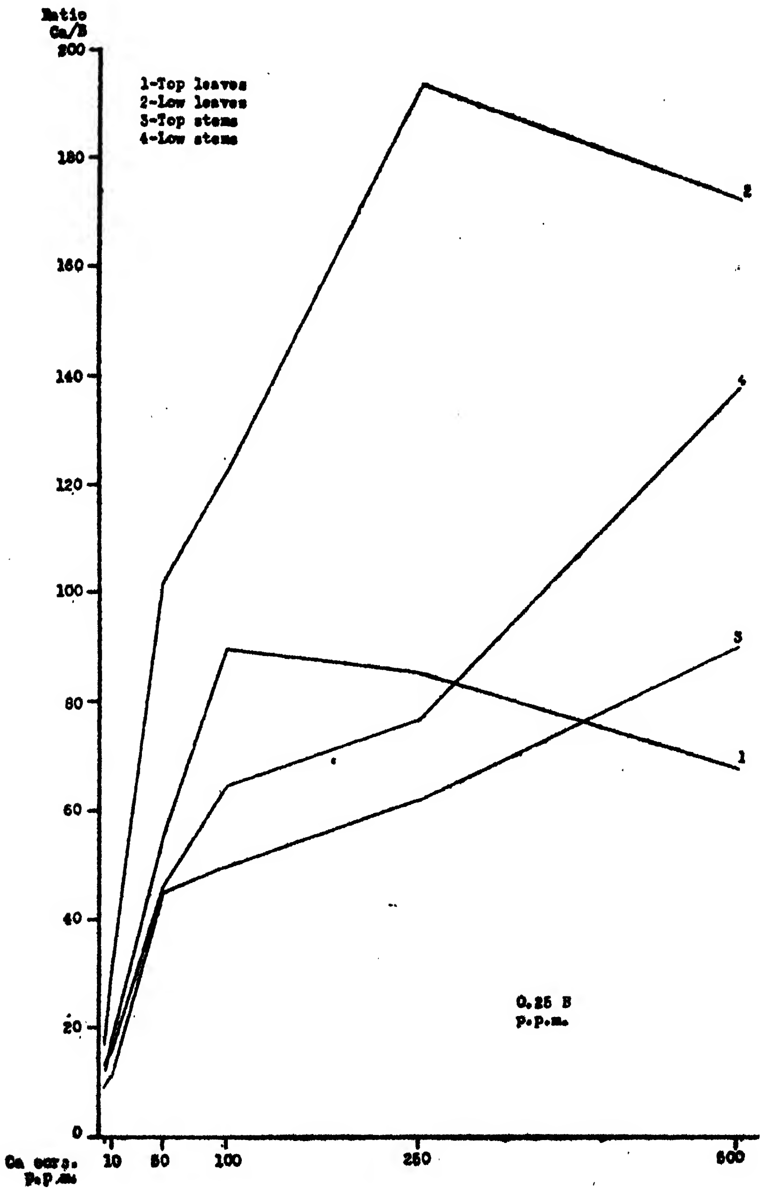

FIG. 10.—Ratios of total calcium to total boron in each fraction of corn plants grown at 0.25 p.p.m. boron plotted against calcium concentration in the substrate.

because of the greater accumulation of calcium and boron in the older tissues of the plant, the Ca/B ratios of the lower leaves were higher than those of the top leaves in all but one case. The same trend followed with regard to the Ca/B ratios of the lower stem and the top stem fractions except that at the highest boron concentration there was not much difference between the Ca/B ratios of the top and the low stem tissues respectively at any nutrient level of calcium except the highest (500.0 p.p.m.).

As can be seen from table 11 and figures 9, 10, 11, 12 and 13, as the calcium increased at a given boron level, the Ca/B ratio increased in the majority of cases. On the other hand, as the boron increased at a given calcium level, the ratio decreased.

From the analytical results and Ca/B ratios presented for both series of corn, it is evident that a certain relationship exists between calcium and boron which affects the metabolism of the corn plant, but which, however, is not so striking as with the tomato (4, 37). The quantitative results obtained in the second corn series for the total and soluble boron and calcium contents of the composite samples did not confirm the qualitative observations made, namely, that the boron deficiency symptoms were increasingly severe with increasing calcium concentration of the substrate. However, when a

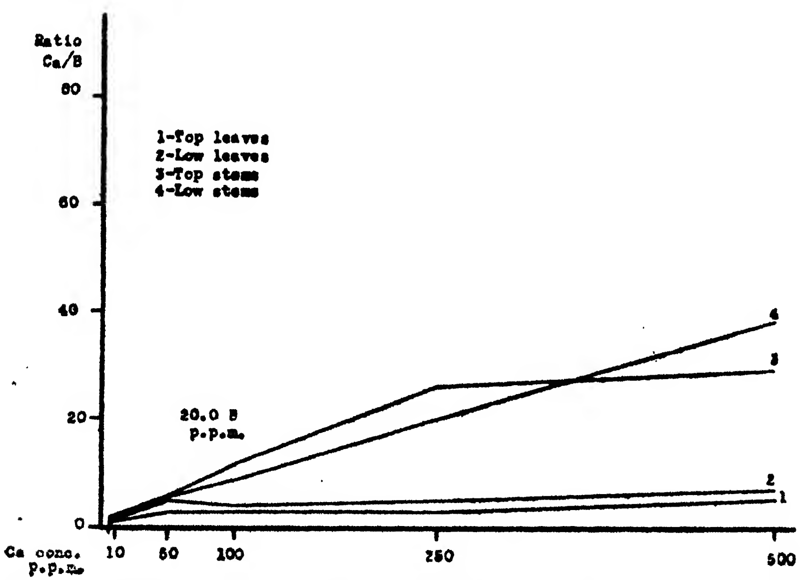

FIG. 11.—Ratios of total calcium to total boron in each fraction of corn plants grown at 20.0 p.p.m. boron plotted against calcium concentration in the substrate.

representative plant from the culture supplied with no boron at the highest calcium levels was fractionated, the analytical results for total and soluble boron for the top leaves were in agreement with the qualitative observations made on the tops of these boron deficient plants. Since a considerable amount of total and soluble boron of these boron deficient plants was found in the older tissues as compared with the top leaves, probably this was the reason why the analytical data of the composite samples did not corroborate the qualitative observations. The higher total and soluble boron of these fractions masked the small amount of total and soluble boron of the top leaves when all the tissues were mixed to take the composite sample, and, therefore, little or no difference was evident between boron contents of whole top samples of different nutrient treatments. The results further suggest that there is probably little

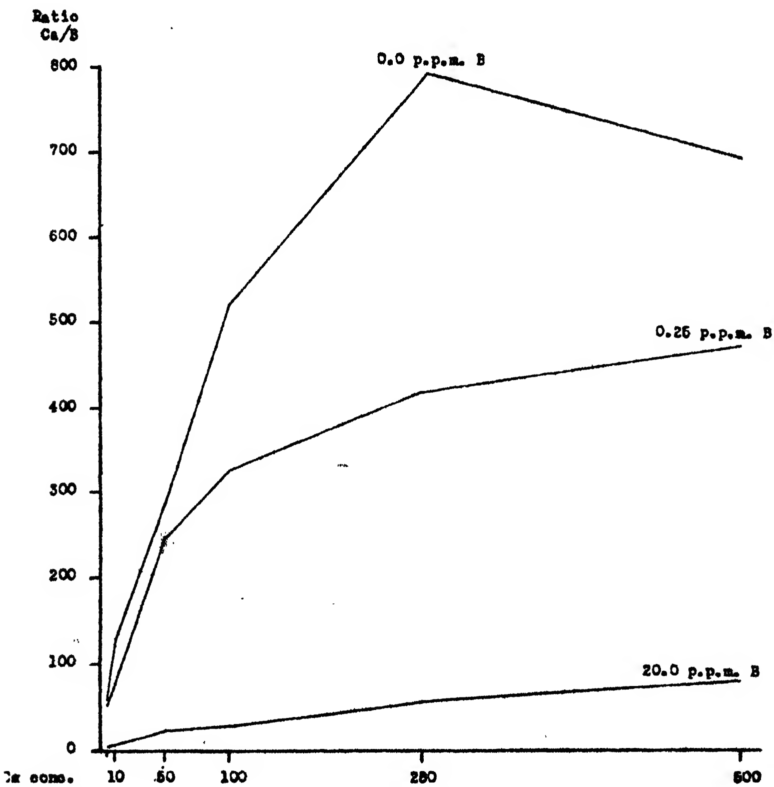

FIG. 12.—Ratios of the averages of tissue contents of total calcium to total boron of the four different plant fractions of corn plants grown at nutrient levels of 0.0, 0.25, and 20.0 p.p.m.

if any translocation of soluble boron from the older tissues of the boron deficient plants to the top leaves where meristematic activity is at its maximum. It should be mentioned at this point that it took a considerable time for the boron deficiency symptoms to appear in these cultures in both series. However, it took less time than in the similar cultures grown in the fall season (46). The fact that the boron requirements for corn are rather low (18) and that a relatively large proportion of this element is in the soluble state in the plant tissue may explain the late appearance of the injury due to boron deficiency in the top leaves and roots. This also suggests why corn plants made fairly good growth up to the time when the deficiency symptoms appeared. It is probable that the late appearance of boron deficiency symptoms in plants, to which boron was not intentionally supplied, was due in part to the presence of boron as impurities in the salts used. In fact, it was found necessary to repurify one of the salts, namely, $CaCl_2$ for the second series, by recrystalization.

As was pointed out previously, the Ca/B ratios of the boron deficient plants were high. Plants that received no boron in the substrate and which were supplied with calcium concentrations of 5.0, 10.0, and 50.0 p.p.m. had a much lower Ca/B ratio than those

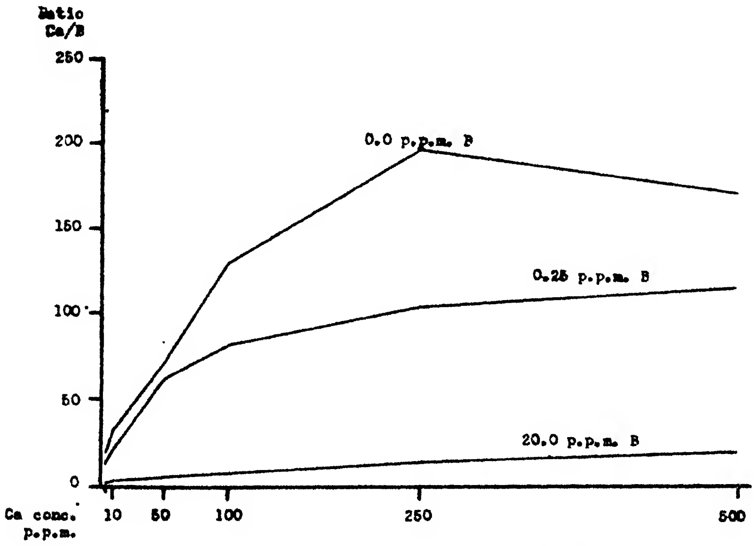

FIG. 13.—Ratios of total calcium to total boron of whole tops of corn plants grown at boron levels of 0.0, 0.25, and 20.0 p.p.m. plotted against calcium concentration in the substrate.

at the highest calcium nutrient levels and showed either slight boron deficiency symptoms or no symptoms at all. It appears that the combination of high calcium and deficient boron in the substrate upsets the normal metabolism of the plant more seriously than a combination of low calcium and deficient boron.

Neither the quantitative data for total and soluble boron of the composite nor the fractionated portions of the plant confirmed completely the qualitative observations made with regard to a decrease of boron toxicity in the plants supplied with 20.0 p.p.m. boron as the calcium concentration of the substrate increased. On the other hand, the calculated Ca/B ratios for the composite and fractionated portions (table 6 and table 11) of the plants furnish some interesting information. It is in the quantitative relationship between the calcium and boron within the plant that the decrease in the severity of boron toxic symptoms can be associated. The plants that showed relatively mild boron toxicity symptoms, which were the plants grown with the highest calcium concentrations of the substrate, had higher Ca/B ratios than those showing more severe boron toxicity symptoms. This indicates that a combination of high calcium and high boron in the substrate tends to favor a more normal metabolism of the plant than a combination of low calcium and high boron, which brings about a disturbance in the metabolic activities of the plant.

The plants grown in the substrate containing 0.01 to 0.25 p.p.m. boron were devoid of any boron deficiency or boron toxicity symptoms, thus indicating that their metabolism was normal. These plants had Ca/B ratios which were intermediate between those of boron-deficient and boron-toxic plants.

The quantitative results presented in this report for total and soluble calcium in the corn plant definitely show that the quantitative relationship between these two elements within the plant plays a very important role in the metabolic activities of the plant. Moreover, the data show that a certain balance between calcium and boron must exist within the plant to fulfill the requirements for normal growth and development of this monocotyledon.

SUMMARY

Corn plants were grown in sand culture using the continuous flow method with six different kinds of nutrient solutions which contained different calcium and boron concentrations. A qualitative and quantitative study was made of the response of the plants to the different calcium and boron levels. The results may be summarized as follows:

1. Plants showing symptoms of boron deficiency were found by chemical analyses to have a low content of total and soluble boron and those showing symptoms of boron toxicity a very high content of total and soluble boron.

2. Boron deficient plants were characterized by the appearance of elongated, white transparent stripes in the newly formed leaves. The growth of boron toxic plants was stunted, their top leaves yellow or yellow-green and margins and tips of lower leaves brown and dead.

3. Composite samples of the whole tops of plants showed by analysis that both total boron and soluble boron were largely independent of the calcium concentration in the substrate, except that soluble boron content of the plants grown with the highest boron level (20.0 p.p.m.) was less when supplied with nutrient levels of 500.0 p.p.m. calcium than with the lower calcium levels.

4. The accumulation of calcium in the composite tissue samples of the tops was found to be largely determined by the calcium concentration in the substrate, except that at the highest nutrient level of boron (20.0 p.p.m.) the calcium content of the tissue of plants grown with high nutrient levels of calcium (100.0, 250.0, 500.0 p.p.m.) was higher than those of plants grown at lower nutrient levels of boron.

5. Boron deficiency symptoms increased in severity with increasing calcium concentration of the substrate throughout the range of the four highest nutrient levels of calcium, except that somewhat more intense boron deficiency symptoms were detected at 250.0 p.p.m. calcium than at 500.0 p.p.m. calcium concentration. Top leaves of boron deficient plants grown at 0.0 p.p.m. boron and which showed boron deficiency symptoms had, in general, lower total and soluble boron content than top leaves of plants grown at the same boron

level but at the two lowest calcium levels which did not exhibit boron deficiency symptoms. The older tissues of these plants showing external boron deficiency symptoms had a considerably higher total and soluble boron content than the younger tissues (top leaves).

6. The results of this study indicate that there is a limited rate of translocation of boron from the lower portions to the top leaves of boron deficient plants.

7. Boron toxicity decreased in severity with increasing calcium concentration of the substrate.

8. Increasing the concentration of boron in the culture solution resulted in a marked increase of total and soluble boron in all tissues of the plant.

9. There was a greater accumulation of calcium and boron in the older tissues of the plant than in the tissue where meristematic activity was highest.

10. The calcium content of the tissues was determined to a large degree by the calcium concentration of the substrate and was largely independent of the nutrient level of boron.

11. Differences in the soluble calcium contents of the top leaves of calcium deficient plants were related to the soluble boron content of the tissues, which in turn were determined by the boron concentration of the substrate.

12. The quantitative relationship between calcium and boron within the plant plays an important role in the metabolic activities of the plant. Boron deficient plants had a high Ca/B ratio, while boron toxic plants had a very low ratio. Plants which apparently were healthy in all respects had intermediate ratios.

13. At a given boron level, increments in the calcium concentration in the substrate caused an increase in the Ca/B ratio of the tissues.

14. At a given calcium level, increments in the boron concentration in the growth media caused a decrease in the Ca/B ratio of the tissues.

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A SOCIO-ECONOMIC STUDY OF SOUTHWESTERN PUERTO RICO

INTRODUCTION

In overpopulated areas, like Puerto Rico, which in addition is characterized by scarcity of natural resources and a strictly agricultural economy, it is very essential that the minds of the governmental officers responsible to the people be constantly in action searching for practicable ideas and programs which may help to relieve the tremendous pressure of the population over the scanty resources. Otherwise, the only logical result to expect is a chronic and increasingly low standard of living together with all other economic and social problems naturally tied to it. The final expectation, therefore, can be nothing else but complete ruin and disaster. Fortunately, the people who have the responsibility of the present government of Puerto Rico have been always conscious of this fact and are trying by all possible means to make the best use of the existing resources in an

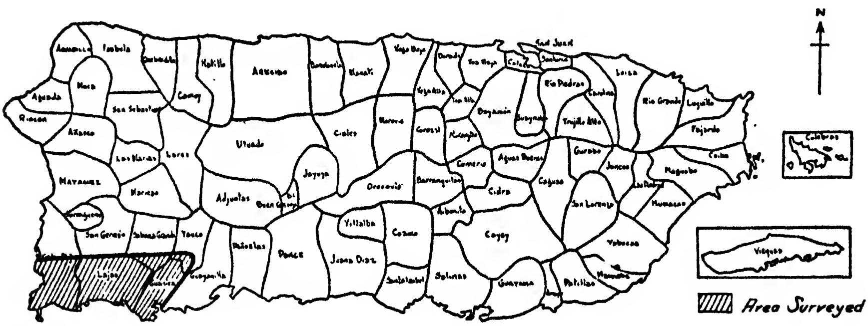

Figure 1. Map of Puerto Rico showing the area surveyed.

attempt to face the problem intelligently so as to raise to the maximum possible level the standard of living of the population.

According to the above-mentioned governmental policy, proper directives have been issued to all agencies and institutions which in one way or the other may give a hand to alleviate the situation. In the year 1941–42, the government directed all agricultural and other related agencies to integrate their efforts in an attempt to delineate action-plans which may contribute effectively to increase the productivity of the land. One of the first things considered was the development of the Lajas Valley located at the Southwestern part of the Island.

The Lajas Valley region, including its surroundings, comprises around 100,000 acres which extend from the municipality of Yauco to the southwestern tip in the municipality of Cabo Rojo (figure 1). As will be described later, this is a very fertile but dry region which, if properly developed, could be made one of the most important agricultural areas in Puerto Rico. For this purpose a committee named the Lajas Valley Com-

mittee, was officially created. Its main objective was to coordinate governmental action in such a way as to arrive at the most effective and practicable plan for the development of this area.

The first problem encountered by this committee was the lack of reliable information on which to base a scientific development plan for the area. The immediate task, therefore, was to look for the lacking information. Consequently, the first step taken was the preparation of a very inclusive outline of the needed information regarding all social, economic, and other technical aspects involved. The responsibility of gathering the information was given to the different agencies which were thought to be best suited for each purpose. The studies concerning the economic classification and use of the land as well as those related to the farm management problems of the area, were considered to be of paramount importance. The Department of Agricultural Economics of the University of Puerto Rico was made responsible for these phases of the general study.

As indicated above, the general objective of this report is to provide the Lajas Valley Committee with the necessary information regarding the classification, use and management of the lands in Southwestern Puerto Rico. Besides this general purpose there are other specific ones which are to be pointed out later in the discussion of the objectives of each main aspect of our study.

DESCRIPTION OF THE AREA

Social Background

Population[1]

The Lajas Valley area in Southwestern Puerto Rico includes the entire population of the municipalities of Lajas and Guanica, about half the rural population of Cabo Rojo, and about a third of the rural population of Sabana Grande. In 1940 the population of the area was 42,748, of which 34 per cent lived in Lajas municipality, 30 per cent each in Guanica and Cabo Rojo, and 6 per cent in Sabana Grande. In 1940, 81.9 per cent of the population was rural, compared to 69.7 per cent in Puerto Rico. The total population density, on an approximate area of 134 square miles, was 319 persons per square mile, compared with 546 persons per square mile in Puerto Rico. The highest density was 423 persons per square mile in Guanica. The average rural population density was 244 persons per square mile compared with 381, the average rural density of Puerto Rico. Of the total population of the four municipalities 17.6 per cent was colored in 1940, having increased slightly from 17.4 per cent in 1930.

[1] Data from report prepared by the Puerto Rico Planning, Urbanizing and Zoning Board based on the 1940 Census.

Rate of Population Increase. Since 1899 the population of the area has nearly doubled. Its rate of increase was 98.3 per cent, or slightly greater than the rate of 96.1 per cent for Puerto Rico. The period of greatest population increase occurred between 1899 and 1910, when the population of the area increased from 21,554 to 30,177, or 40.0 per cent compared to Puerto Rico's total population increase in that period of only 17.3 per cent. The direct cause of this increase was undoubtedly the establishment of Guanica Central shortly after 1900.

In all other census periods, except that between 1935 and 1940 the population of the area increased more slowly than that of the Island as a whole. The period of least growth occurred between 1920 and 1930, in which period the rate was only 2.3 per cent, compared to Puerto Rico's population increase of 18.8 per cent in that period.

Urban and Rural Population. In 1940, the proportion of the total population of the Lajas Valley area which was rural, 81.9 per cent, was considerably larger than that of the total population of Puerto Rico, which was only 69.7 per cent. However, the population of Guanica municipality was only 39.1 per cent rural. The town of Lajas, with a population of only 2,294, was included with the rural population, for the U. S. Bureau of the Census classifies as rural all persons living outside of towns with a population of 2,500 or greater.

Although the period in which urban population has been reported in the Lajas Valley Area has been too short to make possible any accurate estimate of trends, it appears that the proportionate increase in urban population has been slower than that recorded for all of Puerto Rico. However, in absoluted numbers, the urban population of the area increased 26.6 per cent between 1930 and 1940, while the rural population increased only 19.0 per cent. This strictly urban growth has taken place entirely in Guanica municipality.

In an area as small as the Lajas Valley, the recorded population increase of specific towns is often more valuable than a study of urban population alone. During the time that the population of the area doubled, the population of Guanica and Lajas towns more than tripled. The rate of increase has been consistently high during this whole period, and Lajas has grown more than Guanica. Undoubtedly the predominance of large land holdings has contributed to town growth in the area. The large number of agricultural laborers who work on the sugar cane estates have little opportunity to settle on the level valley floor, and must live in towns or small roadside villages, or in the slopes of the hills north of the valley. In addition, the greater employment possibilities and the greater social contacts and better living conditions available in town offer an added incentive to live there.

Natural Increase and Migration. Like many areas of predominantly

rural character, the Lajas Valley Area has had a high birth rate and a high rate of natural increase. However this high birth rate is not reflected proportionately in the recorded population increase of the area, indicating that there has been a surplus of population which has emigrated to other areas, presumably those of greater economic opportunity. In the 10 year period from 1931 to 1940 inclusive, 10,415 births and 4,234 deaths were recorded in the municipalities of Lajas and Guanica. If to the births and deaths for Lajas and Guanica are added the number of births and deaths in Cabo Rojo and Sabana Grande proportional to the per cent of their total population lying within the area, the estimated number of births in the Lajas Valley Area is 16,614 and of deaths 6,969. The natural or gross population increase is therefore 9,645. However the Census recorded a numerical increase in the population of the area of only 7,228, indicating that only about three fourths of the gross population increase of the area remained there, and the rest emigrated. Since the probabilities of under-enumeration of births is more likely than that of deaths, the estimate of gross population increase and thus of emigration, is conservative.

The situation is much the same in the municipalities of Lajas and Guanica alone. The gross population increase in the same period was 6,181, but the net recorded increase was only 4,729—a net emigration of 1,452 persons.

The weighted average birth rate for the area was 10 per cent higher than the average for Puerto Rico during the same period. Since the average death rate was lower than that for the Island, the rate of natural increase for the area is higher than that for the Island. There is little significant difference between the rates for the municipalities lying predominantly or entirely within the area. Apparently Sabana Grande responds to other influences, but their effect on the average for the area is slight.

Age and Sex Distribution. Age distribution in the Lajas Valley Area does not vary greatly from the distribution typical of Puerto Rico. A lower proportion is in the productive working ages, that is, from 15 to 44 years—and a higher proportion is in the youthful age—14 years and under—particularly under 5 years of age. In general, the age distribution in the area tends to be more typical of the rural population of Puerto Rico than of the urban.

Sex distribution like age distribution does not vary greatly from that typical of Puerto Rico, and again the tendency is toward rural rather than urban characteristics. In the four municipalities there are 102.5 males per 100 females, while in all Puerto Rico the ratio is 100.8 to 100. Curiously enough, Guanica, which has an urban population proportionally twice as great as Puerto Rico, has a significant predominance of males.

Employment. Of the 56,007 persons living in Lajas, Guanica and Cabo Rojo municipalities, 20,312 were reported in the labor force in 1940. There

was therefore one actual or potential wage earner per 2.8 persons as compared to 1 per 3.1 persons in all Puerto Rico. However, since the census was taken during the harvesting and grinding season for sugar cane, the employment figures given are seasonal, and higher than if the census had been taken later in the year.

There were 13,643 males and 6,669 females reported in the labor force, giving a ratio of one male per 4.1 persons, and one female per 8.4 persons. The highest ratio of male to female workers, 3.9 to 1, was reported in Guanica, and the lowest, 1.6 to 1, was reported in Cabo Rojo. Of those persons over 14, sixty per cent are in the labor force as compared to 52 per cent in Puerto Rico.

The majority of those employed were in private employment, only a little more than one per cent being employed in public emergency work. About 96 per cent of those in the labor force were employed, except in public emergency work, compared to 85 per cent in Puerto Rico. Of those employed, 62 per cent were wage or salary workers as compared with 72 per cent in Puerto Rico. The remainder are employers, self-employed or unpaid family workers. In Guanica 82 per cent of those employed were wage or salary workers, due to the influence on employment patterns of Guanica Central; 73 per cent were so classified in Lajas, and 52 per cent in Cabo Rojo. In the latter a large proportion of those employed were women doing needlework at home, accounting for the lower proportion of wage or salary workers.

The greatest single source of employment was in agriculture, principally in sugar cane farms. Ninety-nine per cent of those employed in agriculture were men. Sugar cane farms employed proportionately more of the labor force than in Puerto Rico, since in the latter, other farms, principally tobacco and coffee, employed a large group. Needlework at home was the second greatest source of employment and those employed were for the most part women. Transportation, wholesale and retail trade, and personal service provided employment for proportionately fewer persons than in the rest of Puerto Rico.

Education and Literacy. The population ten years and older of the four municipalities was 72.7 per cent literate in 1940, compared with the average of 68.5 per cent for Puerto Rico in the same year. The variation between municipalities was slight. Cabo Rojo had the lowest literacy, 71.7 per cent, and Lajas the highest, 74.3 per cent. Thirty per cent of those 10 years and older were able to speak English; compared with 27.8 per cent for Puerto Rico. There was a considerable variation between municipalities with respect to ability to speak English, Guanica had the highest, 42.8 per cent due to the presence of a small colony of continentals in connection with the Central. Although the actual number of continen-

tals and persons born in other United States possessions amounted to only 85 persons in 1940, and represented less than 7 tenths of one per cent of the population, this proportion was nearly twice that of the Island as a whole.

According to data for 1943 submitted by the Insular Department of Education, there are 68 elementary urban and rural schools in the Lajas Valley Area, with 134 schoolrooms, 23 second unit classrooms, and 11 vocational school classrooms, with a total enrollment of 6,829 students. Census data give approximately 16,000 persons between the ages of 5 and 19 in the Lajas Valley Area in 1940, which means that at least 60 per cent of those of school age are not enrolled in school. In Cabo Rojo and Sabana Grande some children living within the area may be attending schools outside the area, which may reduce the proportion of those not enrolled to approximately 50 per cent, which is close to the proportion for the Island as a whole. In Lajas, Guanica and Cabo Rojo the per cent enrolled is 44, and 43 respectively, but in the two wards of Sabana Grande lying within the area the proportion is only 17 per cent.

In Lajas there are 8 second unit and 5 vocational classrooms and in the four wards of Cabo Rojo, lying within the area, there are 15 and 6 respectively. However, in neither Guanica nor in the two wards of Sabana Grande are there any second unit or vocational classrooms reported. Of the rural schools in the area, the majority are of one classroom.

Social Classes

There is a definite and marked social stratification in a rural society. The Southwestern Region of Puerto Rico is no exception. Strong social consciousness exists in the area involving differences of status which make groups of individuals separate into social classes from the rest of the community. This class consciousness depends very largely upon the competitive, conflictive, or cooperative relations of the different groups. It is not possible to distinguish sharply the factors which are causal in determining the social classes but, in Puerto Rico (including the Southwestern Area under study) the principal factor responsible for this stratification is the economic factor, that is, income, occupation, size and value of land holdings, the nature of land tenure, etc. Other causal factors such as education and ability, racial or nationality composition of the population, mobility and length of residence of families and the organizations in which the members of the society participate, although important, are secondary in nature.

The social pyramid of the area consists of three sections; namely, the upper, middle and lower section; which represent the three different classes which have developed there.

Upper Class. In the upper class the big landholders and the owners

and high employees of sugar mills are found. It is a small number of families with the highest income, and the complete control of most of the property and practically of all the activities in the area.

In the upper class the concept of primacy of lineage is frequently present. These families have developed name and wealth. For several generations they have established a prestige for a family name that distinguishes them from the rest of the people, not only within the community, but all over the Island.

The families in the upper class, because of their solid economic status and high education can afford to have a high standard of living. They are in very good health, have good housing facilities, excellent automobiles, very good diets and excellent clothing. The size of the family of this class is the lowest on the average consisting of four or five members in total. Generally, they have plenty of servants at home to do all domestic jobs and other employees to take care of the flower gardens, lawns and hedges.

These upper families are able to buy the daily newspapers, weekly magazines, novels and poetry books as well as other business publications. They usually prefer to send their children to private city schools and later to universities in other countries. Being on an advantageous economic position they are members of the most select social clubs in the Island; and they are able to make frequent trips to the capital city to attend dances, meetings, etc. They spend their vacations, two or three months during the year usually after the grinding season, travelling outside the Island. It is interesting to observe that they go to the capital city to buy most of their clothing and a great part of all the house necessities. In their opinion, they are unable to find what they want in the nearby towns or cities, where they only buy those things which they get short of, or which are most essential to their daily needs.

The upper class may be divided into two sub-classes, the upper-upper and the lower-upper. This division is fundamentally of an economic nature. The big landowners are in the upper-upper group, and the higher employees are in the lower-upper group. The big landowners, even if living close to their properties, are not in direct contact with the so-called inferior employees and with the laborers. They may get in contact with the higher employees usually on business matters, but not very frequently. They regard themselves as superior people who have lots of employees working for them. The higher employees, to them, are "very good and nice people with great ability to work on large business." However, they very seldom share with them social activities and gatherings. It is very rare that they come in contact with the other employees and laborers; however, the latter know well who they are, and recognize them as the owners of the holdings where they work. To the laborers it is a kind of attraction

to see them. The laborers hear their immediate boss talking about Mr. X. In their conversation with the other laborers they refer to them as "very rich people who are enlarging their capital by the exploitation of their labor and lives."

Middle Class. Next to the upper group of families rank those of middle size farmers and of the office employees, engineers, "mayordomo" and time-keepers. The bulk of these families constitutes the group which may be called the middle class of the area. There exist, however, differences in salaries and prestige among them with a consequent stratification into two further groups which may be called the upper-middle and the lower-middle classes.

The upper-middle group usually have a higher education, higher income, and consequently enjoy higher levels of living. They live in relatively good houses, either personally owned or the property of the sugar mill. These houses are usually provided with the essential comforts, though not expensive. Usually these families own an automobile for their personal use. Their salaries permit them to have a home servant which helps in doing the cooking and cleaning of the house. Their diets, health and clothing are relatively good. Most of their services and necessities are obtained in the nearest town or city. However, they make trips to the capital city once or twice a year, where they may have a good time and where they obtain some of the luxurious things which they are able to afford.

The upper-middle's family consists of five or six members. The children usually attend the public schools of the nearby town. After High School they are frequently sent to the University of Puerto Rico for a degree. Very seldom are they able to send them to universities outside the Island, and when they do, it is on the basis of sacrifices. It is important to observe that they have a high sense of morality and that they criticize deviations from their standards which are seen in the higher groups.

The upper-middles do not establish a definite line of distinction from the lower-middles. They share with them certain social activities such as birthdays, baptisms and Three Kings' Day parties. The classes above look at them as "good" and "efficient" people; however, they do not share social activities together. Some of the upper-middles, because of a better position in relation to their superiors, can enjoy certain privileges which indicate a tendency for mobility to a higher level. This, however, is not very frequent.

As indicated before, this group enjoys higher incomes and, therefore, can afford to spend some money on daily newspapers, magazines, novels, poetry books and other technical reading material. Because of their relatively privileged position in relation to the upper class, they are sometimes allowed to use hunting grounds, tennis courts, golf courses and other recreational

facilities owned by the higher class. In spite of this privilege, unwritten social regulations restrict its use to certain specific periods or days of the week.

The lower-middle class is formed by the smaller size farmers and the lowest salaried employees such as clerks, stenographers, typists, etc., who, because of a lower level of education or the fact that they may come from poorer families of the vicinity regard themselves as socially subordinated. Their attitude toward those above them, as well as the behavior of the upper classes, has contributed greatly to set them apart as a class group.

The lower-middle, because of their lower incomes, cannot afford to have a level of living high enough to be considered satisfactory. They spend a higher proportion of their income on food and other necessities and a very small amount on other luxurious things such as education, recreation, etc. They live in small houses either personally owned, provided by the sugar mill or rented. Their families generally consist of six members on the average. Their health, housing facilities, and diets can be described as fair. They own no private automobile and use buses or public cars as the general means of transportation.

These lower-middles are the first to use the rural country schools. Their children go to these schools usually up to the fourth grade. Afterwards they are sent to public town schools until they get their High School diploma. Very seldom a child is able to go to the University, and if they do, it has to be with some kind of outside help from a relative, or from the government in the form of scholarships. Of course, they have to be exceptionally good students to receive this kind of help. Persons belonging to this class are able to buy one of the daily newspapers, and once in a while a novel or any other book.

In their relationships with those above them in the social pyramid, they are somewhat timid. They are accustomed to receive orders and to accept them as final, no matter if they do not agree. When they receive a deference from the upper-middles, they feel as if they have been greatly honored by their superiors. Their social recreational activities are mostly limited to birthday celebrations, baptisms, Three Kings' Day parties, and occasionally, going to the movies in town.

Lower Class. Below the lower-middles, the largest and perhaps the most important group is found. These are the sugar factory and agricultural laborers. Because of the importance of this group, and due to the fact that most of the problems resulting from social and economic maladjustments are tied up to this underprivileged class, it is intended here to describe it in more detail.

First, it is convenient to establish a line of distinction which stratifies the laborers into two groups, one of which ranks a little higher than the

other, socially speaking. This group is the upper-lower; and the reason why they are on a higher social level is mainly due to the type of work they perform. Sometimes those laborers who have attained a higher grade in school, or have acquired more experiences through age or through travelling as laborers in different regions of the Island are also recognized as superiors. These upper-lowers have a higher social prestige that is recognized by both upper and lower classes. In fact, the reason why they have better jobs as laborers may be very likely due to this recognition. They usually perform such jobs as foreman, tractor and railroad machine operators, truck drivers, etc. They feel proud to have their superiors rely on them to get the work done; and consequently, they put all efforts to do it as best as possible. In a way, they serve as links between the bulk of unskilled laborers and the lower-middles. Although it is true that they keep good relations with the unskilled laborers, they sometimes are looked by them as "people who are no better than we are but trying to gain favors from the bosses."

The level of living of the upper-lowers is a little higher than those below them—the lower-lowers—however, the difference cannot be considered significant. It is true that they are paid a little higher, but the difference in salary, when expressed in terms of standard of living, does not amount to much. For this reason, and because of the fact that it is very arbitrary to set a definite line of distinction, it is intended here to discuss their social and economic problems as a single group.

The average size of the families of the agricultural and factory workers is about 6 members. On the average, they have an annual income of around $250. However, a large number of these families obtain incomes which average a little over $150 annually. Family expenditures are greatly limited by their low incomes. They spend about two-thirds of their income in food, nearly 10 per cent in clothing and very insignificant amounts in house furnishings, fuel and light, medical care, personal care and recreation, and only three-tenths of one per cent in education. The reason why they spend such a small proportion of their income on education is obvious. As a result of this situation they are unable even to satisfy the important necessities of life. Their children attend the rural schools usually up to the fourth grade and very seldom attend the schools in town.

Living Conditions of the Lower Class

Diet. The diet of the agricultural and factory workers is entirely insufficient in quantity and quality for the normal development of the human body. It consists principally of starchy vegetables, dried cod fish, rice, beans, cornmeal and black coffee or coffee with milk. According to investigations made, it was found, for example, that 85 per cent of the laborers'

population breakfasted on black coffee, coffee with milk, or in a few cases coffee with milk and bread. Lunch for 88 per cent of them consisted of starchy vegetables, rice and beans, starchy vegetables with codfish and rice with beans, or cornmeal; and 93 per cent of the total had for supper rice and beans, or rice, beans and fish, the latter by only a few families. It was also found that the caloric intake was short and that the protein, fat, mineral and vitamin contents in the diet were entirely inadequate.

The effects of bad nutrition which extend through the years and even through generations is disastrous to a population. General debility caused by a deficient diet and the exhausting physical effort which the laborers undergo result in the loss of resistance against disease. It must be taken into consideration that this diet is difficult to substitute because it is not easy to obtain one which produces as many calories at such a low cost and which, moreover, contains some of the essential components, being at the same time liked by them.

Housing. A larger number of the agricultural workers as well as of the factory workers live in houses owned by the landlord. The housing facilities are very poor in general. The most common type of house is constructed of wood with a galvanized iron roof. Frequently the houses were constructed in places where the soil is very poor or swampy, in order not to use the better lands which are used for cultivation. The houses of these workers have only one or two rooms and a kitchen situated in a small lean-to shed. There is an average of 3.5 persons for each bedroom available.

The furniture in these houses is scanty and of the cheapest quality. A large proportion of them have only a few benches or empty boxes for chairs, a small table, one or two cots, and a homemade wooden box. However, occasionally a house is found which has an iron bed and some chairs.

Only a little over one-half of the houses have latrines of a simple type. In the remaining homes there are no latrines or sanitary installations of any type.

The fact that laborers live in houses which are the property of the landlord without paying rent, results in a status of housing insecurity. Until recently, if at any time the owner estimated that a laborer family was not rendering productive services to their interests, they were able to force them out of their properties. This situation is very well described by the term "agregado" (squatter) which is the common name given to them.

Clothing. Workers' families are far below the minimum adequated clothing requirements. A study made by the Home Economics Department of the University of Puerto Rico showed that the minimum adequated clothing requirements per year for a family of six should be about $116.00 (October 1, 1942 prices). Although these minimum requirements were very conservatively calculated, they are considerably higher than the amounts spent on clothing by workers' families. In other words, they were spending

from one-fourth to one-third of the amount of money which was necessary for minimum clothing standards. The typical average worker has a pair of pants, two shirts, one underwear set, a pair of shoes, and an old straw hat. His wife's wardrobe is more or less the same amount. Many male children wear no clothing at all. Some children wear either a blouse or drawers, seldom both.

Water supply. There are no water systems in the rural areas to provide water to the laborers. The majority of the families use water from wells, irrigation ditches, polluted rivers or springs, or use rain water collected from the roof and stored in cisterns. Occasionally people use a water straining device for collecting rain water. With a population density of 546 persons per square mile in Puerto Rico, as revealed by the 1940 census, and an almost total lack of facilities for the sanitary disposal of human excrement in the rural areas, there are practically no surface sources from which pure water can be supplied for drinking purposes, without being first properly treated. Consequently, there exists a continual threat of waterborne disease epidemics among the rural working class.

Health. The sugar cane areas of Puerto Rico are located on the coastal plains and the interior valleys of the Island. They are the best and most fertile lands in the country, but due mainly to topographical conditions, they are also the most unhealthy, because endemic diseases such as malaria and bilharsiosis are very common and bring the mortality rate in these regions to a higher level than in the mountainous areas.

Generally speaking, it may be said that the diseases which do most harm to the population are caused by exogenous transmissible agents: malaria, which prevails in the coastal areas and tuberculosis and intestinal parasites, which are today found over all regions. Mortality from gastric enteritis is the primary cause of infant mortality in these areas. Malaria, tuberculosis and intestinal parasites are the most serious problems of adults. It may be noted that general and infant mortality is higher in the sugar cane zone than in Puerto Rico as a whole.

There is an average of about 5,000 inhabitants per doctor in the sugar cane areas in comparison with 12,151 inhabitants per doctor in the other areas. These figures indicate that the supply of doctors in the sugar cane zones, although not sufficient, is higher than in the zones where sugar cane is not grown, which is an indication of the greater wealth and prosperity which exists in these zones in comparison with the areas where cane is not cultivated. It should be pointed out, however, that doctor services are very seldom available to workers' families due to their inability to pay for them. In spite of the greater supply of doctors, the mortality rate is higher, which is a further proof that there exists a greater number of illnesses in this area and that it is a more unhealthy region.

The health situation described above is characteristic of the sugar cane

laborers' families including those of the Southwestern part of the Island. It is evident that their poor health has its deepest roots in their difficult economic situation which results in an entirely inadequate diet, and the squalor in which these people live.

Castes

Caste groups in Puerto Rico are not so important as class groups. For this reason social classes were described above in very much detail, inasmuch as they are the most important factor of social stratification in the rural society of Puerto Rico.

The population of Southwestern Puerto Rico, the same as in the Island as a whole, is predominantly white. However, the percentage of colored people in the sugar cane area is by far higher than in other areas of the Island.

Caste lines in the social structure of Puerto Rico are more rigidly established by those groups which are higher on the social pyramid. Its importance decreases in the groups which have a lower level in the social ladder. Among the working class it is common to see marriages of white and colored people and the sharing of social activities between them. No significant evidence can be found as to differences in the work they perform. They are employed regardless of their color. However, although no clear distinction of caste lines can be observed, it has not completely disappeared. There are still many white families who hesitate to accept colored people as social equals and who do not participate together in social activities. To conclude, the tendency for the caste line to disappear is a movement which has developed mainly among the lower groups and which very probably will continue its development in an upward direction.

Institutional Organization

The Church. A very high percentage of the rural people belong to the Roman Catholic church. This represents the general faith of the people of the Island which developed under the Spanish Government. However, although rural people are considered to be very religious, they very seldom attend religious services. The rural church has developed very little on the island, especially in the sugar cane areas where very few, if any, are found. They are usually located by the side of a public road outside of the big land-holding. Their buildings are fairly good, but very poorly equipped.

The rural churches do not have a resident priest or pastor. They reside in the near towns from which they come to serve. The program of activities of the rural church is very limited. In the case of the Rural Roman Catholic Church practically the only service offered is a mass held usually once a month.

Churches of other denominations have recently increased their interest in the rural people. Their membership has been increasing. However, it is by far much lower as compared to that of the Roman Catholic Church. The development accomplished by these other churches has been mostly among the lower classes, since the higher class people have very little or no tendency at all to change their religion. They have a sense of social prestige tied up to the Catholic church. Members of the upper classes very seldom attend the rural churches. To satisfy their social consciousness of superiority they prefer to attend Catholic churches in town where they can associate with people of their same category.

As indicated above, the rural people are segregated into two main groups in relation to religious activities. This segregation is based on the location of the church which they attend. It is interesting, though, that both groups mostly attend the Roman Catholic Church. This segregation, however, may cause difficulties which must be carefully faced in any attempt to develop a religious program for the rural people.

The School. School facilities existing in Southwestern Puerto Rico have been discussed previously. This section will mainly attempt to describe briefly the social characteristics and influence of this institution in relation to the rural people.

School attendance, as well as church membership, is similarly divided into two groups on the basis of social classes' attitudes. The division is based on those who can and cannot afford to send their children to town schools.

The most common type of rural school serving the rural area is the one-room one teacher school. It is a governmental public school where attendance of children up to certain age is supposed to be compulsory. The highest education which is generally offered is the fourth grade. The school house is located by the side of a public road in a lot which is generally the property of the Government. Academically, teachers are, generally speaking, well prepared because of the opportunities for improvement offered by the Government. They are paid on a twelve months' basis but their salary is relatively low. Teachers are not exactly full members of the community in which they serve, but live usually in the nearby town travelling back and forth every day. In spite of this fact, the rural teacher is the outstanding professional leader of the community, and one of the persons most interested in the welfare of the rural people.

Close contact of the different social classes does not occur in the rural schools. As stated before, members of the upper classes prefer to send their children to the town school, and the uppermost classes have a preference for private city schools. The enrollment of the rural school, therefore, comes principally from the lower and middle classes. The lack of interest in rural school activities, logically present in the higher classes, is one of

the most serious problems of the rural schools. In spite of this situation they have achieved considerable progress in implementing its program in the community.

The Insular Government has been developing a program of Rural Education Improvement. Rural schools are being centralized into the so-called "Rural Second Units," which offer academic training up to the ninth grade, besides training in vocational education. Eventually, these "Second Units" will predominate in the rural areas of Puerto Rico and will offer better and less expensive education, as well as more facilities for social improvement in the community in general.

Local Government. There is no form of central local government for the whole Southwestern area under study. For governmental purposes the Island is divided into seven districts, each one including several municipalities. The latter is the smallest unit of government whose seat is centered in the town. In the Southwestern area of Puerto Rico there are four of those municipalities involved, namely, Cabo Rojo, Lajas, Guanica and Sabana Grande. Insular governmental activities such as public health, police service, education, justice, revenues, etc., are handled at the municipal level. The Southwestern area of Puerto Rico is, therefore, not a unit of local government by itself, but includes four municipalities from which governmental services are directly or indirectly obtained.

Services and Activities

Hospital Facilities. Hospital facilities are very limited in the Lajas Valley Area. There are 7 general hospitals with a total of 101 beds in the towns of Lajas, Guanica and Cabo Rojo. Four of the hospitals are private, having a third of the total number of beds. The rest are municipal hospitals. There were 1.7 beds per 1000 recorded population in 1939; Guanica had the highest proportion, 3.4 beds per 1000 population, and Lajas the lowest with only one bed per 1000 population. Since the town of Cabo Rojo lies outside the area proper, only 4 hospitals totalling 58 beds in Lajas and Guanica are actually located within the area. The nearest District Hospital at Aguadilla is too far from the area and, therefore, it should be removed from consideration here. The proposed construction of a District Hospital at Mayaguez would improve to some extent the facilities for hospitalization available to the population of the Lajas Valley Area.

Medical Services. In the areas where sugar cane is cultivated in Puerto Rico there exists an average of around 5,000 inhabitants per doctor. Doctors reside in towns and very seldom visit the rural zone, except their very best clients of the upper class. The upper class also get their medical services in the capital city or in the best private clinics of the largest cities. The middle class depends on the private doctor and small hospitals

of the nearby towns; and the lower class depends on the governmental public health services that may be available.

Sugar cane workers are covered by State Insurance Funds, collected from the employers. The State provides medical assistance and hospitalization to all insured workers who are injured while at work. It also provides compensation payments to injured laborers who, as a result of their injuries, are permanently, partially, or totally incapacitated for work.

An additional type of medical service is sometimes offered by Sugar "centrals" to agricultural laborers and their families. It is of a charitable nature and operates in this way: The sugar central hires a doctor in town and pays him either on a per patient or per time basis. Any laborer or member of a laborer's family in need of medical assistance should first obtain from an employee in the office a written authorization, so as to be examined by the doctor. If the doctor is paid on a per patient basis, the laborer has to see him in his town office. On the other side, if he has contracted to serve on a per time basis, the laborers have to wait for his periodical visit to the "central". Occasionally this charity help is expanded by helping the laborers who cannot afford it to buy the medicines prescribed.

Recreation. The degree of participation in recreational activities varies for the different social groups. There are different recreational activities; however, in none of them is there participation of all classes together.

The upper class has a great part of its recreation outside the area. They belong to very selective clubs in town which they attend regularly. They also visit the capital city to attend social meetings and parties, and also travel abroad for pleasure. In addition, the members of the upper class have their own recreational facilities. They keep tennis courts and golf courses for their use, but are very exclusive as to the persons who may share them. They also attend good theaters in town, if available.

The middle class members have most of their recreational activities within the community limits. Sometimes the "central" or big landholders keep forest grounds in the marginal lands of the area, which they use for hunting. Usually, members of the middle class share this facility but its use is restricted to certain specific periods. Baseball and basketball teams are organized in the community. The big landholders permit sometimes the use of certain open fields for this purpose. Horseback riding is another sport widely in use among the middle class member. Outside of the community the members of this class go to the cinema in town and to cock fights celebrated nearby.

The lower class participates very little in recreational activities. The young members participate to some extent in baseball and basketball games at school. The recreation most widely enjoyed by the lower class is the

popular travelling vaudeville that visits the community periodically, especially during the grinding season.

All the classes in general have other private social activities and celebrations such as dances, birthdays and other parties, but attendance at them is almost exclusive for the members of each class.

Meeting Places. There are no specific meeting centers in the area. The most common meeting places are the country retail stores and the office building grounds during pay days. In addition to these two places, the school serves that purpose too, especially during the celebration of school activities. The most common meeting places for the members of the middle class in the community are their own houses. The upper class seldom meet together in activities in the community. Their meetings are held in private clubs and other social gathering places in town.

Other Activities. Very few other activities are celebrated by or for members of the community. The most common are those held at the school by parents, teachers and/or students. The outstanding activities that hold the attention of everybody are the activities of the labor unions and those of the political parties.

Interest and Pressure Groups

The only interest and pressure groups in the life of the area are the labor union groups, the big landowners as members of the Association of Sugar Producers, and the political parties. There exist in the Island two labor union groups; namely, the General Confederation of Laborers and the Free Confederation of Laborers. The objective of the two labor unions are the same, that is, the improvement and betterment of the laborers. However, they are segregated, principally because their leaders belong to different political parties.

Commonly, laborers strike every year at the beginning of the grinding season. Usually it takes several weeks to settle the dispute, which results in wage agreements for the season. Neither the labor strikes nor the settling of the dispute is carried on a community level basis. They are island-wide problems handled by the Association of Sugar Producers and the top leaders of the labor union involved. The strikes are very important events in the community because they arouse considerable expectation and activity.

The local leaders in labor union movements are very seldom members of the community. They often live in a nearby community or a neighboring town.

The other pressure groups in the area are the political parties. The activity of these groups comes only once every four years before general elections. The upper classes, in general, are affiliated with the conservative

parties and the lower classes with the social reform party. Always there has been a great struggle between big owners and laborers during the political campaign. Owners use all sorts of pressure techniques to force laborers to vote for the conservative Parties. In 1940, for the first time, a social reform party called the Popular Democratic Party, gained control of the Government in the Island. This party has already started the Social Reform Program they offered to the people. One of its outstanding phases is the Land Reform Program, and undoubtedly the most interesting to the people of the rural area, because of its great bearing on the social and economic life.

Physical Background

Geology[2]

The Lajas Valley extends from Yauco on the east to Boqueron Bay in the west. Its south wall is formed by the Cretaceous San German limestone and tuff. The band of San German limestone appears five times in the tightly compressed folds of the Upper Cretaceous pyroclastic rocks, between the south coast in the vicinity of Parguera and the Guanajibo valley. nearly all these Cretaceous rocks dip south and plunge into the Caribbean Sea. The arches or anticlines rose from 2,000 to 5,000 feet above the adjacent synclines, and from coast to coast, the individual folds measure from one to two miles. The northern boundary is less strongly set off from the low hills of complex mountains. The width of the valley is approximately three miles, with a length of over 27 miles. Southwest of Lajas the valley narrows, then levels at Guanica and Boqueron bays to an altitude of 150 feet feet just south of Lajas. The underlying rock of the lowland is chiefly tuff with small patches of shale.

Excavation of the Valley. The Lajas valley was excavated by subsequent streams working on tuffs and ashy shale, the non-resistant zone of Cretaceous rocks. The central and eastern portions of the valley were carved by the waters of the Cain, the Flores and the Susua rivers located respectively at the north of Sabana Grande, San German and Yauco and all flowing into Guanica Bay. The western portion of the valley was carved by the Boqueron River and its branches.

Submergence of the Valley. The Lajas valley submerged below sea level. In the Post-glacial Period (Pleistocene Age) the western waters of the Atlantic Ocean and the Caribbean Sea connected Boqueron Bay and Guanica Harbor. The Cretaceous ridge of southwestern Puerto Rico was then an island. The subsistence of the Lajas Valley was unrelated to the

[2] Data on the geology of the area from a report prepared by Dr. J. S. Bonnet—Head of the Department of Soils of the Agricultural Experiment Station of the University of Puerto Rico.

regional submergence of forty feet which provided both of its ends with the bays of Boqueron and Guanica. The subsistence of these bays was probably accentuated by the lowering of sea level during the development of the Wisconsin Glacier.

Filling of the Valley. The valley was filled by the fluvial erosion of intermittent streams and by the Susua River in the extreme west of the Guanica lowland. The filling was probably correlated with insular uplift and tilting.

Relation of the Tertiary Coastal Plain to the Older Series. No part of Puerto Rico shows more clearly the relation between the coastal plain and the oldland than the region near Guanica on the south coast. The Tertiary has been deposited upon a very hilly oldland representing the dessected eastward pitching end of the Boqueron-Yauco anticline. Immediately south of Yauco the hills are of crystalline limestone of the older series and these are overlapped on the southeast by the Tertiary cuesta. Although they are more or less interrupted by gaps, permitting direct access from the flood plain of the Susua River eastward to the Tertiary, these oldland hills can be traced in a swinging area as far south as Guanica. Here, just east of the town, some bedded volcanics are associated with the limestone. They strike northeast-southwest or east-west and are presumably a continuation of the formations having an east-west trend at Guanica Central. The presence of a large hill of Tertiary as well as abundant occurrences of the basal gravels proves that this valley had reached approximately its present development before Tertiary time. This belief, that modern erosion changes are not to any considerable degree accountable for the present size and shape of the older series hills, but that they are simply being unburied of their Tertiary cover, is abundantly strengthened by a study of the district adjacent to Guanica Central. At Guanica Central the oldland hills can be seen actually emerging from beneath the coastal plain, and on their flanks there still remains a coating of chalk, attesting the recency of their unburial. This deposit may be seen at the base of the crystalline limestone hill near the stone-crushing plant of the Guanica mill. Nearer to Guanica Central, the coating left upon some of the dark older series volcanic rocks appears like a sheet of plaster or white-wash only a fraction of an inch in thickness.

Reddish Sands in Southwestern Puerto Rico. The presence of a thin coating of reddish, siliceous sand covers part of the surface of the southwestern tip of Puerto Rico. The rocks upon which this sand rests are not extensively exposed, but where seen it is tuff of the same general character as that of Ensenada. The origin of the siliceous sand is probably in the numerous quartz veinlets which occur in the shale and tuff; also from chert masses in these rocks. The red color is due to iron oxide coating the grains and preserved in the arid climate which now characterizes the extreme

southwest corner of the district. The concentration of sand at this point is most likely the combined work of streams and sea. Conclusive evidence of former streams entering this area from the north of the playa suggests the presence at one time of a stream of considerable size. The level character of the surface is in large part the work of the sea when it stood at a higher level.

Topography[3]

The Lajas valley itself is bounded on the north by a ridge of hills, ranging in height up to some 900 feet above sea level, which separates it from the Guanajibo Valley; and on the south by another secondary ridge of hills some 300 to 800 feet in height which separates it from the South Coast. It comprises the flat floor of the valley together with its flanking slopes and has a width of about three miles; extending in an eastward direction for a length of some 17 miles from the west coast to the Susua River. Its flat bottom in general rises slowly on a slight grade from Boqueron Bay on the west coast to a low summit (50 feet above sea level) at the Palmarejo road, and then descends eastward to the level of hightide at Guanica Lake. Considerable portions of the valley bottom, known as the "Anegado" are below sea level and are swampy. The second area of the lowlands includes the Coastal Plains to the south which occur in irregular width, along the Caribbean seaboard between the southwest corner of the Island and Guanica. The sloping lands bordering these areas are of limited extent merging quickly into rough and steep hills.

Soils

The cultivated soil series of Lajas Valley cover approximately 34,801 acres. A brief classification of the soil series and acreage covered by each of them is reported in table 1. A complete description of these soils is found in the Soil Survey of Puerto Rico.

Besides the soils indicated in table 1, there are also 4,518 acres of flooded alluvial clays, of the Guanica series, that if properly drained, can also be cultivated.

The alluvial clays of the valley are poorly drained. Successful farming operations require, therefore, adequated attention to the drainage problem. In the Aguirre clays the drainage is further impaired by salt concentration due to seepage and evaporation.

Tests made by the Soils Department of the Agricultural Experiment Station at Rio Piedras have revealed that a conductivity ratio over 128/150, where the numerator expresses the specific conductance of the first-foot

[3] Data from report prepared by the Puerto Rico Water Resources Authority.

surface of soil and the denominator that at the average four-foot depth, in a 1:2 soil suspension of Aguirre clay, is detrimental to the growth of sugar cane, the most important crop in Lajas valley. It was found that those fields with a conductivity ratio below 172/234, can be leached with five feet of fresh water to a salt concentration favorable for cane growth. It was also found that there are about 5,000 acres of alluvial clays in Lajas valley which have an excessive salt concentration injurious for crop growth. This salty area may be reclaimed with gypsum or sulphur.

TABLE 1. ACREAGE OF ARABLE SOILS IN THE LAJAS VALLEY*

Soil Series	Classification	Acres
Fraternidad	Alluvial and colluvial clay	8,139
Aguirre	Alluvial clay	7,881
Jacana	Residual from andesitic tuffs and tuffaceous shales	4,709
Yauco	Residual from limestone	3,095
Caguas, Sabana Seca	Planosols	2,257
Santa Isabel	Alluvial clay	2,161
Paso Seco	Alluvial	2,145
San Anton	Alluvial	2,086
Lajas, Aguilita	Residual from limestone	717
Teresa, Coloso (poorly drained)	Alluvial	503
Descalabrado	Residual from tuffs	466
Cabo Rojo	Residual from old marine	358
Toa	Alluvial	179
Coloso	Alluvial	105
Total		34,801

* Estimate made by Dr. J. A. Bonnet, head of the Department of Soils, Agricultural Experiment Station, University of Puerto Rico.

Rainfall[4]

The Island of Puerto Rico, lying within the tropics and surrounded by the equatorial waters of the Atlantic Ocean and the Caribbean Sea, enjoys the abundant rainfall which is characteristic of many tropical island regions. The amount of rainfall, however, in spite of the relatively small area of the Island, varies greatly in different locations, ranging from less than 30 inches a year at some places on the coastal plains, to as much as 200 inches in the high mountains of the northeastern section. This diversity is due principally to the effect of the wind and topographic relief. High mountains form a more or less continuous barrier across the Island from east to west; the prevailing northeast trade winds sweeping in from the ocean drop most

[4] Data from report prepared by the Soil Conservation Service, Puerto Rico; and by the Puerto Rico Water Resources Authority.

of their rains on the northern slopes of this divide. These conditions result in a narrow belt of relatively dry country along the south coast of the Island which includes also the Lajas Valley area.

As a general rule, rainfall in Puerto Rico decreases from east to west. In the Southwest section of Puerto Rico, this general rule is evidently reversed, showing a steady increase from east to west. The normal rainfall at Samán, Desengaño, Beatriz and Santa Rita, all of which lie within the Lajas Valley area and about in the same parallel of latitude, shows a steady increase from east to west. In the above order named, Samán is the most westerly station and Santa Rita the most easterly. The normal

TABLE 2. RAINFALL DISTRIBUTION IN SOUTHWESTERN PUERTO RICO BY GAGING STATIONS AND BY MONTHS

Month	Saman		Costa		Desengaño		Beatriz		Santa Rita		All Lajas district	
	1942	Normal	1942	Normal	1942	Normal	1942	Normal	1942	Normal	1942	Normal
	inches											
January	1.05	1.18	0.35	0.83	0.80	0.99	0.25	1.12	0.41	0.71	0.25	1.27
February	0.00	1.99	0.00	1.41	0.00	1.97	0.95	1.64	2.25	1.51	1.00	1.96
March	0.50	2.32	0.00	1.52	0.35	2.13	1.70	1.73	0.30	0.93	1.85	2.26
April	6.20	2.07	1.10	0.85	4.40	1.76	2.55	1.46	4.81	2.36	3.35	2.45
May	6.20	5.42	2.70	4.19	7.00	6.02	4.35	4.69	7.91	4.44	6.66	5.65
June	2.95	2.48	1.70	2.10	2.90	2.26	3.05	1.95	3.60	2.38	2.71	2.66
July	6.55	3.62	4.30	1.80	4.80	3.91	4.50	3.14	2.70	2.19	4.16	3.72
August	6.70	5.65	2.45	4.01	4.70	5.39	3.55	4.11	0.98	3.66	6.55	5.09
September	2.30	6.55	3.20	4.31	2.80	6.30	4.35	6.08	6.11	4.48	2.49	6.68
October	8.75	5.55	9.42	4.85	8.65	5.55	7.10	6.69	4.16	5.90	6.00	6.13
November	4.80	6.01	1.95	3.22	4.30	5.54	5.15	4.08	5.67	4.21	7.00	5.83
December	4.60	2.66	2.65	1.35	5.00	2.60	0.70	1.84	0.57	1.61	2.00	2.27
Total	50.60	45.50	29.82	30.44	45.70	44.42	38.20	38.53	39.50	34.38	44.02	45.97

average rainfall for these stations are 45.50, 44.42, 38.53 and 34.38 inches, respectively (table 2).

Records show also that in this area there is a decreasing trend from north to south. For instance, the station of Costa, which lies closer to the coast line has an average rainfall of 30.44 inches.

Table 2 indicates also the monthly average precipitation for the area as a whole. The average yearly rainfall in the Lajas Valley is 45.97 inches. In tropical areas, where the temperature is high, the humidity low, and the rate of evaporation high, this amount of rainfall results in an arid to semi-arid climate.

Rainfall is not only scarce in the Southwest but is also poorly distributed. The general rainfall pattern is similar to that for the rest of the Island with a five months' dry season from December to April and a distinct rainy

period from May to November. Fortunately, this rainfall distribution, though not the amounts, conforms to the requirements of the major crops grown in the area, that is, sugar cane, cotton and corn.

The general rainfall pattern is the same for most stations in the area. There exists average rainfall in June and July, increasing in August, to a maximum in September or October, with a drop in November. The next five months from December to April constitute the dry season, and then a very decided peak occurs in May, almost reaching the rainfall of September and October.

There exist variations from year to year in the amount of precipitation, but in 1942, the year in which the farm management survey of the area was undertaken, the rainfall condition was approximately normal.

Economic Background

The presentation of the economic background of Southwestern Puerto Rico will be limited only to the discussion of marketing and industries in the area. Other economic aspects such as land tenure, credit and transportation facilities will be described separately in later sections of this thesis.

Marketing

To understand better the marketing activities carried on in this area it is better to look over the different agricultural products separately.

Sugar cane, as will be shown later, is by far the most important crop in the area. Sugar cane is transported from the field to the factory in ox-carts, trucks, or railways. Although the Guanica Central is the only sugar mill lying in the Lajas Valley proper, part of the crop is also sent to other nearby sugar mills.

The business relations between sugar cane growers and mills are usually governed by a grinding contract stating the terms under which the cane is ground. It should be added here that these contracts have to be made in accordance with certain legal stipulations established by insular laws and by the Agricultural Adjustment Administration. Perhaps the most important section of this contract is the one dealing with the method of payment. The farmer receives from 63 to 65% of the sugar produced, the percentage varying in accordance to the sucrose content of his cane.

The farmer may sell his sugar or may let the central do the marketing. The latter method is the most common. All the sugar produced in Puerto Rico is marketed to the United States. The central discounts all marketing expenses and liquidates the remaining part to the farmer.

The Puerto Rico Cotton Marketing Association was organized in 1935 for the purpose of assisting farmers to market their products. Any farmer

engaged in growing cotton may obtain membership and market his product through the Association. Up to 1941, this Association with headquarters in the Northwestern producing area handled all the cotton produced in the Island. Since 1942, cotton has also been marketed through a private dealer located in the southern producing area. The Cooperative Association, however, has continued handling most of the cotton crop, and the prices obtained by farmers through this agency have been always slightly higher.

Both of the above-mentioned firms maintain country warehouses scattered throughout the producing area. Cotton is transported to these warehouses by either ox-carts, trucks, or by railways. From the warehouses the produce is taken to the gins owned by the aforementioned concerns. All the lint cotton is finally exported to the United States.

The cotton cooperative establishes prices for the different grades of cotton delivered by the producers using the so-called arbitrary price differential method. From the gross sales of cotton and cotton seeds they deduct the administrative, ginning and marketing expenses plus a certain amount to build up reserves. The amount left is distributed to producers on the basis of prices arbitrarily fixed by the Cooperative for the different grades delivered. This method of determining the prices paid serves to stimulate growers to produce a larger proportion of high quality cotton. The second cotton dealer, although being a private concern, has followed very closely the price-fixing policy established by the Cooperative.

Other farm products produced in the area are sold by the farmers themselves, either directly to the consumers, to country dealers, or at the public markets especially at those located in the nearby towns. There are public market places in each one of the towns lying within and around the area, however, only those at Mayaguez, San German, Yauco and Ponce may be considered of importance. Very seldom, and only in the case of large producers, minor crops are taken to the distant market places of the Island.

Industries[5]

There are only a few industries of significance in Southwestern Puerto Rico that are not directly dependent upon agriculture. The needlework industry, the production of salt, the fishing industry, and the manufacture of clay products—pottery, tiles and bricks—are perhaps the most important, followed by charcoal and bark stripping for tanning production.

Salt Production. The southwestern part of the Island is, as stated before, an area of very low rainfall and extremely high rate of evaporation, thus conditions are especially good for the production of common salt from sea

[5] Data from report prepared by Mr. Donald F. Griffin, Planning Technician, National Resources Planning Board, San Juan, Puerto Rico.

water by natural evaporation in artificial ponds. There are already several salinas along the coast in response to these ideal conditions.

Southwestern Puerto Rico produces almost 30,000,000 pounds of salt per year. As yet there are no salt refining plants. The crude salt is merely ground locally and used for cooking and preserving. The relatively high price of imported refined salt puts it beyond the reach of the great number of low income consumers, who are forced to use crude salt.

A salt refining plant might be one of the projects to be carried out in the south coast area, which could supply refined salt to the Island. Furthermore, the Island could cover its own requirements of chlorine, caustic soda and hydrogen, which are obtained by the electrolytic decomposition of salt (sodium chloride). The present annual consumption on the Island of these products is about 2,000,000 pounds of salt, but the projected industrial developments in edible oils, soaps, and paper will, upon completion, probably increase this requirement to 3,000,000 pounds of salt. The development of plants for preserving and curing meats and fish would mean further consumption of salt.

This salt industry could be established more advantageously in this area since fuel and distribution facilities will be about the same at any other point of the Island while the basic raw material will be at hand. A thorough study by the Puerto Rico Development Company on conditions, and possibilities of these developments is very advisable.

Fishing. The most important fishing centers in southwestern Puerto Rico are Puerto Real, Boqueron, and Guanica, where probably 200 families rely on fishing for their living. The area is highly favored for the fishing industry because of the irregularity of the shore-line, the numerous spawning and feeding grounds, and the regularity of its adjacent sea bottom. An estimated 20,000 pounds of fish are landed weekly at the above-mentioned ports, but this quantity might be increased many fold if better boats, gear and up to date cold storage, refrigeration and warehousing facilities were available.

There is under consideration the organization of farmer-fisherman cooperatives which would create a central outlet for fish and also make arrangements for the sale of the catch. Substantial savings would be effected through centralized purchase of gear and supplies. Tracts of land of one half to one acre might be distributed to present or potential fishermen. Such real incentives to the fishermen would undoubtedly result in an increase of the catch; and a better system of handling and distribution of fish and fishery products would mean higher income and a better standard of living for fishermen. As in the case of salt production a thorough study on this industry should be also undertaken before embarking on a development program of this type.

Bark Stripping for Tannin Production. The species *Rhizophora* or Red Mangrove, most commonly used as a source of tannings, contains from 30 to 38 per cent of tannins of the catechol group. Several hundred acres of this species exist in southwestern Puerto Rico. The recent inauguration of a tanning industry in Puerto Rico resulted when, as a means of obtaining preservatives for fish lines and nets, the U. S. Fish and Wild Life Service at Mayaquez developed an economical method of extracting the tannins from the mangrove bark, which can compete favorably with imported tannin. This extract has been successfully tried out in the treatment of skins at tanneries located near Mayaguez and at Cataño. It has been reported that the skins treated compared favorably with those treated with quebracho extract imported from South America. As a result of this successful experiment, the Insular Forest Service made available 1500 acres of mangrove forest at Boqueron and La Parguera. Fifty men were put to work cutting trees and stripping 3000 pounds of bark per day, while the extraction plant employed three men. As three thousand pounds of bark will produce 1500 gallons of tannin extract, or enough to treat 3000 pounds of green hides, the equivalent of 1700 pounds of leather, and as Puerto Rico's total present requirement for locally tanned leather, averages 5,000 pounds per day, it is estimated that approximately 150 men could be permanently employed on tree cutting and bark stripping operations alone. Present requirements of the fishing industry are 6000 pounds of bark annually to preserve fishing lines and nets. Future requirements may increase to as high as 30,000 pounds per year.

Charcoal Production. Charcoal is used for fuel throughout the Island. Charcoal production will probably remain a subsidiary farming operation in spite of the fact that there are some mangrove forests and the Guanica forest belonging to the Insular Government in the southwestern part of Puerto Rico that might yield considerable wood for charcoal purposes. In general, however, wood suitable for charcoal purposes in this area does not exist in large quantities.

Other Industries. Quarries might be opened in the huge deposits of limestone in the Lajas area in order to produce limestone for commercial uses. Furthermore research is needed on this subject.

The livestock industry, if proved to be economically feasible in certain sections of the area, could certainly be improved by intensification along the line, from the better raising practices to the processing of the animals with the resulting by-product industries, such as the making of leather, glue and fertilizer.

The tourist industry is another possibility for development in the area. The region has many features such as dry climate, forests, beaches, fishing and scenic vistas which might be very attractive to tourists.

Information on other industries such as needlework, the manufacture of clay products—pottery, tiles and bricks—is not available and it is recommended that studies on these lines should be undertaken.

LAND CLASSIFICATION OF THE AREA

Introduction

The importance of efficient use of the land in an Island like Puerto Rico, with 546 persons per square mile, is evident. Studies on land utilization and land classification are basic to the intelligent guidance for more effective land use.

The lack of a systematic study of land use and land classification is acutely felt in Puerto Rico. On several occasions government officials and students of the Puerto Rican situation have ventured opinions on land use in the Island which have not been substantiated by facts. There is the danger that opinions of this nature may influence public action. Therefore, the need to provide scientific facts upon which to base public action is quite evident.

Land classification studies in the United States have been very fruitful of results. They have served as orientation of teaching and of extension and research programs in agricultural economics. It has been found that most farm managements recommendations made without regard to land classes are less valuable than studies where land classes are taken into consideration. Land classification studies provide an excellent background for the planning of public services to rural areas. Extension recommendations made on the basis of land classification have a much better chance of favorable reception by farmers. Land use and classification studies yield facts which are very relevant to natural resources conservation programs.

History of Land Utilization Studies in Puerto Rico

The Department of Agricultural Economics of the Agricultural Experiment Station of the University of Puerto Rico initiated its activities in the year 1934. As was reasonable to expect the first years were devoted almost entirely to the task of gathering and analyzing basic data on the economic problems of the agriculture of the Island. Therefore, the first studies made, in line with this objective, were mostly farm management and type of farming surveys of the major agricultural areas of Puerto Rico.

In the year 1940, the first study of land use was undertaken. The objectives of this project were to study the utilization of pasture lands from the standpoint of a well-rounded land use pattern and of its income and food producing potentialities. Surveys were initiated in two areas, namely, the Northwestern coast and the Tobacco region. Under this proj-

ect, detailed information was gathered on the use of the land by fields for a number of years and within the 1939–40 crop year. A total of 118 farms in the Northwestern section and of 196 farms in the Tobacco region were surveyed analyzed.

The results of the above-mentioned study proved to be very encouraging and valuable. Therefore, in 1941 the Department expanded the project with the final objective of classifying all the lands of Puerto Rico from the economic standpoint. Its general objective was to help to bring about necessary adjustments to increase the efficiency in the use of land. The municipality of Caguas was selected as the best area to start with, due to the fact that there existed a wide variation of physical and economic factors which were very valuable in arriving at the best system of land classification to follow in other areas. A complete land-cover map of the whole area was drawn. Unfortunately this project had to be postponed. The United States entered into World War II, and, complying with national directives, all the research work had to be oriented toward objectives most directly related to the war efforts. However, the land cover map made proved very valuable to the Puerto Rico Planning, Urbanizing and Zoning Board in the preparation of a master plan intended to determine the best location of communities to be established by the Land Authority of Puerto Rico under Title V of said program. It also proved very useful to the same agency in providing criteria to follow in the preparation of a map of existing and proposed roads of the Island.

In the year 1942, when the idea of working a coordinated action-plan aimed towards the fullest development of agricultural resources in Southwestern Puerto Rico was conceived by several governmental officials, one of the first points considered was the need of making an economic classification of the lands of said area. The information resulting was aimed to help in determining the possibilities for social and economic improvements of the area in regards to the establishment of an irrigation project, agricultural development, land tenure policies, industrialization and improvements of public services and facilities. It was decided that this phase of the study should be undertaken by the Agricultural Experiment Station of the University of Puerto Rico.

Objectives of the Economic Classification of the Lands of Southwestern Puerto Rico

The classification of the land on the basis of the intensity of use to which it is adapted is necessary before a desirable program of land use can be drafted. The general purpose of the economic study of land utilization in Southwestern Puerto Rico is to determine the location and extent of areas of land adapted to different degrees of intensity of use, and to suggest

plans for the development of the resources of the area. A further purpose of the study is to determine the relationship between the intensity of use to which different classes of land are adapted and various factors connected with the organization and operation of the farms of the area.

There are also certain specific objectives in mind. Land classification studies have been found very valuable in appraising lands for taxation and other purposes, in orienting credit and insurance agencies in their rural policies, in rural zoning and land use planning including such programs as resettlements, reforestation, recreation, reclamation and conservation projects, in guiding standards and costs of public services, and in orienting teaching, education and research in agriculture as a whole. All these objectives were kept in mind when undertaking the task of classifying the lands of Southwestern Puerto Rico.

Method of Procedure

Economic land classification involves both inductive and deductive analysis. The inductive process consists of the appraisal of relative success and failure of various types of land use which have been tried or which still exist in the areas being classified. The process is hampered by the fact that relative or absolute success of failure cannot be imputed solely to the type of land use practiced. Other factors, including size of farms, conditions of tenure, availability of operating capital, and efficiency of management are likely to be as strongly influential in determining success as is the type of land use. These obstacles, however, can be largely overcome through judicious and adequate sampling.

Farm survey records provide the best data obtainable not only because a record of actual land use may be reconstructed from them, but also because detailed analysis can be made of labor and capital, costs of production and financial returns. The outstanding merit of farm survey records lies in their exposition of the relationships of land, labor, and capital in actual operating farm organizations. Detailed farm survey records serve their highest usefulness when the sample is selected in such a manner as to provide a representative and adequate cross-section of the several land-types under investigation. The data thus developed are used in the evaluation of the specific land types.

The purely deductive type of reasoning is best exemplified by the budget approach. In practice, the deductive method usually starts with the land-type inventory and appraisal of climatic environment, assumptions as to the adaptability of various crops and livestock, and estimated yields and productions. Using predicted prices of farm products and calculating production cost (assuming reasonably good farm managment techniques) the analysis then proceeds through the farm-budget approach to construct

plans for hypothetically suitable farm units. Some weakness is inherent in this system in the extent to which the structure of logic rests upon assumptions which are not susceptible to ready verification, and to the disproportionate influence which minor variations in imputed production, cost or price exercise upon the net operating income or loss which is the final measure of farm success. Through the deductive approach, tentative hypotheses may be established with regard to the type of land use best adapted to the physical environment and within the existing or projected economic and social setting. These hypotheses are, however, subject to checking through comparison with the hypotheses arrived at through inductive analysis.

The inductive and deductive processes are similar in the respect that both start giving full consideration to the physical characteristics of the soils taking into account physiographic features such as variations in soils, climate, relief, stoniness and native vegetation. Furthermore, both are used in attempting to ascertain within the limits of agronomic adaptation the highest economic, social and technological conditions. The results arrived at by both methods ordinarily may be expected to be in rather close agreement. While each has its limitations, the greatest value lies in their complementary rather than separate use.

In classifying the lands of Southwestern Puerto Rico we followed mostly the inductive type of reasoning. It is true, however, that we were compelled to adapt our method of procedure to the limitations imposed by the special characteristics of the region as well as by the limited funds and time available to do the job.

We had at our disposal the following basic material with which to start the classification:

1. A soil survey map of the area which was prepared by the United States Department of Agriculture in cooperation with the University of Puerto Rico Agricultural Experiment Station, published in 1942.
2. A soil classes map of the area prepared by the Soil Conservation Service at San Juan, Puerto Rico in the year 1942. The soil types of the whole area were associated into eight different classes according to their use capabilities from the soil conservation point of view.
3. A Geological Survey topographic map of the area prepared by the United States Department of Interior.
4. A road map of the area prepared in the year 1942 by the Puerto Rico Planning and Urbanizing Board which includes primary and municipal roads either existing or proposed.
5. A map of land tenancy of the area prepared by the Puerto Rico Planning, Urbanizing and Zoning Board in the year 1943.
6. A total of 240 farms' management records taken in the area for the

crop year 1942–43. These farms were selected in such a manner as to provide a representative and adequate cross-section of the whole area. The survey was made in the year 1943 by the Department of Agricultural Economics of the Agricultural Experiment Station of the University of Puerto Rico. The results obtained from this farm management survey are presented in a later section of this study.

With this material on hand we had enough basis to start the economic land classification of the area. The only thing missing was a land-cover map. Using the topographic map as a base, a number of enumerators visited the area and a map showing the use of all the land was prepared. The scale of the topographic map used is such that 1 inch on the map equals 25,000 inches on the ground. Other maps available were converted to this same scale. A series of symbols were used in the map to represent the different land uses found as well as the farm buildings and other features such as irrigation pumps, electric lines, salinas, etc. This map was brought to the office where boundaries of the different land use areas were carefully drawn.

In determining the boundaries of the different economic land classes, the topographic map was first used. All the information on the road map prepared by the Puerto Rico Planning and Urbanizing Board was transferred to the topographic map Tentative land-class boundaries were traced on the topographic map by superimposing the information available on the soils association map prepared by the Soil Conservation Service, and that of the land-cover map prepared by the Department of Agricultural Economics. The roads information, the topographic map, the soils association map and the land-use map were found to be in general agreement. The lines around areas of different economic land classes were finally drawn on the map after harmonizing doubtful areas through sound judgment and best knowledge of the region.

The final map prepared was based primarily on intensity of land use. A total of eight different economic land classes were drawn and enumerated. The higher the number the less intensively the land was used. A copy of this map is presented at the back.

The different economic classes finally established were defined as follows:

R—Recreational and residential lands.

I—Level lands in intensive agricultural use and requiring no special conservation and/or drainage practices.

II—Level lands in intensive agricultural use but requiring special drainage and/or irrigation practices.

III—Lands in intensive agricultural use but with insufficient rainfall and/or rough topography therefore requiring irrigation and/or complex conservation practices.

IV—Level lands in extensive agricultural use with insufficient rainfall and/or drainage problems.

V—Rolling lands in extensive agricultural use with lack of rainfall and/or insufficient water retention.

VI—Lands in extensive agricultural use with insufficient rainfall and rough topography.

VII—Lands in extensive agricultural use but best suited for forestry and/or recreational purposes.

VIII—Lands out of agricultural use.

The final work done was the comparison of the different economic land classes with respect to various factors. For this purpose the 240 farms surveyed in the area were localized in the map and the land class predominating in each one was noted. It was found necessary, due to the small number of farms that fell in certain class groups, to establish the comparison by combining the farms falling in land class I and II, IV and V, and VI and VII. A very large number of farms fell in land class III; therefore, these farms were left alone as a single group. Thus, a total of four different groups were established for comparison. The relation of economic land class to size of business, land use, livestock, use of pasture land, irrigation, rates of production, labor efficiency, farm expenses, farm receipts, farm earnings, and to farm mortgage indebtedness and other factors, was established; and the results are presented in a later section of this thesis.

DESCRIPTION OF THE FARMS IN THE AREA

Objectives of the Farm Management Study

The study of the farm management aspect of the area was considered by the Lajas Valley Committee to be of paramount importance in providing basic information to legislators, administrators, students of our economic life, and others who may have to counsel or act in the determination of agricultural policies to be followed in the improvement of the area. The responsibility of undertaking this study was put in the hands of the personnel of the Department of Agricultural Economics of the Agricultural Experiment Station of the University of Puerto Rico.

This study is also intended to describe briefly the farms of the area with regard to their set-up, land tenure, cropping system, source of income, expenses, and returns for the operation and management of the farms. It is attempted to discover the reasons for variations in earnings and to show the relationship and influence of certain factors to the financial returns of the farms. This will not only increase the basic knowledge of our agriculture, but will also be of immediate practical value to farmers in adjusting farm operations, aiming towards higher profits.

Method of Procedure

The Agricultural Extension Service and the Land Authority of Puerto Rico cooperated in gathering the field information on which this study is based. The survey method was used. Enumerators visited the farms and asked specific questions to cooperating farmers concerning their farm business for the year 1942–43, and the answers were recorded on a specially prepared form. The information given by the farmers operating larger farms was usually from account books. For smaller farmers the answers given were mostly from memory.

The sample surveyed was elected at random, thus resulting in a representative cross section of the Lajas Valley area.

TABLE 3. DISTRIBUTION OF FARMS AND CUERDAS STUDIED BY MUNICIPALITIES

240 farms, Southwestern Puerto Rico, 1942–43

Municipality	Number of farms	Per cent of total	Cuerdas Total	Cuerdas Per farm	Cuerdas Per cent of total
Lajas	137	57	18,112	132	50
Cabo Rojo	66	28	7,436	113	20
Guanica	16	7	9,247	578	25
Yauco	12	5	807	67	2
Sabana Grande	9	3	1,023	114	3
Total	240	100	36,625	153	100

A total of around 260 farmers were visited in the municipalities of Cabo Rojo, Guanica, Lajas, Sabana Grande and Yauco. When the enumerators returned from the field, each record was carefully checked and if any items were found missing, another visit was made. These records were rechecked in the office and each one was carefully analysed. Records considered to be not representative nor sufficiently accurate were eliminated. A total of 240 records were finally selected for the study.

The Farms and the Farmers

Distribution of Farms and Cuerdas Studied

The 240 farms studied, comprising a total of 36,625 cuerdas, were scattered over the five municipalities of the Lajas Valley; namely, Lajas, Guanica, the southern part of Cabo Rojo, the eastern part of Yauco and the southern section of Sabana Grande (table 3).

Fifty seven per cent of the farms, with one-half of the cuerdas studied, were located in the municipality of Lajas. Cabo Rojo ranked second as

to number of farms studied with a total of 28 per cent. However, it included only one-fifth of the total acreage as compared to Guanica which, with only 7 per cent of the farms, comprised one-fourth of the acreage studied. This shows definitely that the concentration of land is greater in Guanica. As a matter of fact, the sugar cane farms belonging to the Guanica Sugar Mill which lie within the area were included in this survey. As a result, the farms located in Guanica were the largest in size and averaged 578 cuerdas as compared to 153, which is the average size of the farms studied.

Only small sections of the municipalities of Yauco and Sabana Grande lie within the Lajas Valley area. The acreage studied in these municipalities amounted only to 5 per cent of the total. It is interesting, however, to observe the fact that the smallest farms studied, on the average, were located in Yauco.

TABLE 4. LOCATION OF FARMS IN RELATION TO ROADS

240 farms, Southwestern Puerto Rico, 1942–43

Distance to paved road	Number of farms	Per cent of total
Less than 1.0 km	139	58
1.0–1.9	55	23
2.0–2.9	21	9
3.0–3.9	16	6
4.0 and over	9	4
Total	240	100

Location of Farms in Relation to Roads

Transportation facilities exert a considerable influence on the farm business, economic relations, and social attitudes of growers. This factor is especially important in dealing with sugar cane farms because of the fact that sugar cane is a bulky product which needs cheap transportation from the field to the factory. In Southwestern Puerto Rico, which as will be shown later in this report is principally a sugar cane region, good transportation is, therefore, of great significance.

There are very good transportation facilities in Southwestern Puerto Rico. The majority of the farms studied are located on, or very near, good roads usually macadamized. As shown in table 4, 58 per cent of the farms studied are located at a distance of less than one kilometer to a paved road. Around one fourth of the farms are at a distance of from one to 1.9 kilometers and only 4 per cent are located 4 kilometers or farther from the nearest paved road.

Several important insular highways run across the area and many other

gravel or dirt roads are also found. These, however, do not supply the entire needs for roads and thus, some of the farms in the area are located off the roads. The Insular Government very wisely has recognized this situation and is planning new constructions in the area and the improvement of several existing roads.

Land Tenure

In Southwestern Puerto Rico as well as in the other important sugar cane areas of the Island, a great number of the farms are not solely owned by the operators. Some are totally owned, others are totally cash rented, and others are completely sharecropped or managed. It is also very frequent to find cases in which a combination of two or more of these different types of tenure is found on a single farm. For this reason the author believes that the land tenure pattern of the area can be better described by classifying the acreage instead of the farms studied.

TABLE 5. LAND TENURE BY SIZE OF FARM

240 farms, Southwestern Puerto Rico, 1942–43

Size groups	Number of farms	Per cent cuerdas: Owned	Cash rented	Share-cropped	Managed	Total
Less than						
20.0 cuerdas	82	81	10	—	9	100
20.0–39.9	41	68	10	2	20	100
40.0–59.9	28	79	6	2	13	100
60.0–99.9	25	59	6	—	35	100
100.0–149.9	21	62	24	—	14	100
150.0–249.9	17	83	6	—	11	100
250.0–499.9	13	79	17	—	4	100
500.0–999.9	7	68	32	—	—	100
1000.0 and over	6	46	18	—	36	100
Total	240	60	17	*	23	100

* Less than one per cent.

A total of three-fifths of the acreage studied was reported to be owned by the operators, 17 per cent was cash rented and the remaining 23 per cent was managed (table 5). Sharecropping as a type of tenure in the Lajas Valley area is of very little importance.

No direct relationship was found between type of tenure and size of farm as measured by total acreage. However, a little over four-fifths of the acreage in the farms reporting less than 20 cuerdas in total was owned by the operators, as compared to 46 per cent which is the case in the largest land-holdings of 1000 cuerdas or more. In other words, there seems to be a tendency for big land-holders to own less land, in proportion, than small

farm operators. Apparently they have found very effective to increase the size of their farm business through renting of additional lands or by operating them under management.

Topography of Land

Nearly two-thirds of the land studied is of a level topography (table 6). The remaining one-third was classified by the enumerators as broken.

The proportion of level land was found to increase with increases in the size of the farm. Evidently, big land-holders in this area as well as in Puerto Rico as a whole, have not only been able to concentrate big extensions of land, but have also succeeded in controlling the most fertile level lands of the valleys.

TABLE 6. TOPOGRAPHY OF LAND BY SIZE OF FARMS

240 farms, Southwestern Puerto Rico, 1942–43

Size groups	Number of farms	Total cuerdas in farm	Per cent cuerdas Level	Per cent cuerdas Broken
Less than				
20.0 cuerdas	82	911	45	55
20.0– 39.9	41	1,100	47	53
40.0– 59.9	28	1,381	54	46
60.0– 99.9	25	1,893	61	39
100.0–149.9	21	2,526	58	42
150.0–249.9	17	3,148	50	50
250.0–499.9	13	4,094	64	36
500.0–999.9	7	3,909	81	19
1000.0 and over	6	17,663	70	30
Total	240	36,625	65	35

Soil Types

One of the striking characteristics of the soils of Puerto Rico is the wide number of soil types existing. For instance, in spite of the fact that the area under study is a relatively small one, a total of seventy different soil types were reported in the farms studied. This wide variation of soils is not only present in Puerto Rico and in this region as a whole, but also in each individual farm.

Out of the 70 different soil types reported, only 13 amounted to more than 500 cuerdas (table 7). Among them, in order of importance, as measured by acreage, are the Fraternidad, Aguirre and Jacana clays which amounted to 16, 15 and 10 per cent, respectively, of the total acreage studied. Although there were many other soil types present, none of them amounted to more than 6 per cent of the total acreage.

The farms studied were located on topographic and soil maps. It was

possible, in this way, to arrive at the productivity rating of the different soil types. The productivity rating is a numerical expression of the capacity of production of soils ranging from 1 for the most productive soil to 10 for the least productive. According to this rating, the most productive soil type reported is the Santa Isabel clay; but it amounts to only 4 per cent of the total acreage studied. The Fraternidad and Aguirre clays, which are the most important from the point of view of acreage, ranked second in productivity. In general, the soils of the Lajas Valley Area can be described as of a medium to high productivity.

TABLE 7. SOIL TYPES

240 farms, Southwestern Puerto Rico, 1942–43

Soil type	Number of cuerdas	Per cent of total	Productivity rating
Fraternidad clay	5,760	16	2
Aguirre clay	5,516	15	2
Jacana clay	3,814	10	8
San German clay	2,202	6	10
Caguas clay	2,111	6	5
Aguilita stony clay	1,583	4	10
Santa Isabel clay	1,361	4	1
Aguilita clay	1,340	4	10
Amelia clay	883	2	5
Mucara silty clay loam	867	2	7
Lajas clay	636	2	10
Descalabrado silty clay rolling phase	600	2	10
Lajas clay, rolling phase	512	1	10
Other*	9,440	26	—
Total	36,625	100	—

* Includes 57 soil types ranging from 5 to 485 cuerdas.

Farm Population

A total of 72 per cent of the farms studied reported population living on the farm (table 8). In general, a smaller per cent of the larger farms reported farm population. This fact points out again the problem existing in Puerto Rico relative to the squatters or "agregados." The big landholders usually live in nearby towns. They are also very reluctant to allow agricultural workers to live on their farms.

The average operator's family consisted of 5.2 members for all farms and of 7.2 members for the farms reporting. Its average size was found to be larger for those families living on small farms. This corroborated once more the well known fact that the larger families are found among the

people of lower incomes and, consequently, of lower standards of living. Southwestern Puerto Rico is no exception.

There are other families living on the farm which are mostly "agregados", and relatives of the operator in the case of the smaller farms; or agricultural workers in the case of the larger holdings.

As is natural to expect, the larger farms supported a larger population, although the burden is very probably heavier for the smaller ones. The total farm population on the average amounted to 24 persons per farm.

TABLE 8. FARM POPULATION BY SIZE OF FARMS

240 farms, Southwestern Puerto Rico, 1942–43

Size groups	Total number of farms	Operator's farm family: Per cent of farms reporting*	Operator's farm family: Number of persons: Farms reporting	Operator's farm family: Number of persons: All farms	Other farm population (all farm)	Total farm population
				average per farm		
Less than						
20.0 cuerdas	82	89	6.8	6.1	6.0	12.1
20.0– 39.9	41	71	7.2	5.1	5.2	10.3
40.0– 59.9	28	86	7.7	6.6	9.6	16.2
60.0– 99.9	25	68	6.7	4.6	20.0	24.6
100.0–149.9	21	48	7.9	3.8	16.7	20.5
150.0–249.9	17	59	11.1	6.5	20.3	26.8
250.0–499.9	13	31	4.5	1.4	20.5	21.9
500.0–999.9	7	71	5.6	4.0	57.7	61.7
1000.0 and over	6	16	10.0	1.7	258.7	260.4
All farms	240	72	7.2	5.2	18.3	23.5

* Families living at the farm part of the year only were not included.

Age of Operators

The age of the 240 operators ranged from 24 to 85 years. Only 3% were under 30 years of age (table 9). The largest age group, 78 persons or 33 per cent of the total, was from 40 to 49 years of age. The second most important group, 54 heads or 23 per cent of the total were from 50 to 59 years old. This age distribution is about normal and compares favorably with that of other regions in the Island.

Education of Operators

The importance of the level of education of the farmers' group has been emphasized in previous social and agricultural economic publications. Poorly educated farmers are handicapped in understanding the economic factors affecting earnings and are at a disadvantage in handling a farm effec-

tively in these days of commercialized agriculture and strong competition. Another no less important influence of the lack of education is that poorly educated farmers are unable to adjust their farming operations in line with the technical progress. Undereducated farmers, furthermore, are very suspicious and reluctant of papers, signature, figures, government employees, technicians, etc., and tend to prefer the simplest and most informal ways of running a farm. This constitutes a heavy burden and a drawback to

TABLE 9. AGE OF OPERATORS

240 farms, Southwestern Puerto Rico, 1942–43

Age group	Number	Per cent of total
Less than 30 years	8	3
30–39	44	18
40–49	78	33
50–59	54	23
60–69	43	18
70 and over	13	5
Total	240	100

TABLE 10. EDUCATION OF OPERATORS

240 farms, Southwestern Puerto Rico, 1942–43

Educational status	Number	Per cent of total
Not reporting	24	10
No schooling	27	11
Schooling:		
1–4 years	77*	32
5–8 years	72	30
High school	26	11
College or Universtiy	14	6
Total	240	100

* Includes those reporting knowing only how to read and write.

their own business. Agriculture is a dynamic industry and farmers need to be educated and trained enought to keep pace with changing times.

The fact that 11 per cent of the farmers studied did not know how to read and write and that 32 per cent had less than 5 years of schooling is an indication of the tremendous educational job that is ahead (table 10). Only 11 per cent of the operators reported highschool education and the small number of 6 per cent had college or university training. The relative lack of education on the part of farmers is something that should be kept in mind when delineating any development program for the area.

Farming Experience of Operators

The framing experience of the operators of the farms studied can be described as very long, as shown on table 11.

Only 15 per cent of the total reported less than 10 years of experience and nearly two thirds have 20 or more years.

TABLE 11. FARMING EXPERIENCE OF OPERATORS
240 farms, Southwestern Puerto Rico, 1942–43

Years farming	Number	Per cent of total
Less than 10 years	36	15
10–19	48	20
20–29	50	21
30–39	45	19
40–49	35	14
50 and over	26	11
Total	240	100

Organization of the Farms Studied

Invested Capital

The average total investment per farm for the year of the study was $25,675 (table 12). Of this, 82 per cent was invested in real estate, 8 per cent in livestock, and 7 per cent in machinery. The average per farm for these three items was $12,109, $2,147 and $1,803 respectively.

The most important single item of investment was land, which accounted for 76 per cent of the total and averaged $19,504 per farm.

In order of importance come livestock, machinery, and farm buildings. The latter, of which the operator's house was the most important, amounts on the average to 5 per cent of the total or $1,354 per farm.

Equipment made 2 per cent of the investments with an average of $599 per farm. Supplies and other investments represented insignificant items and reached only to $17 per farm.

Machinery and Equipment

The average value of machinery and equipment per farm amounted to $2,402 (table 13). Machinery made three fourths of this value.

Although only 13 farms reported investments in irrigation equipment, this item alone accounted for more than one half of the total value of machinery and equipment. Irrigation equipment is very expensive and though badly needed in the area, it can only be afforded by the very rich land-holders. The same thing happens with the trucks and tractors. Only

very few large farmers reported them but their value per farm amounted to about one fifth of the total.

The value of dairy equipment constituted a very small part of the total. Other miscellaneous items made practically all of the total equipment. The majority of the farmers investigated reported having other equipment which consisted mainly of ox carts, plows, harrows, harness, chains and other miscellaneous tools such as hoes and "machetes". Ox carts are very

TABLE 12. INVESTED CAPITAL

240 farms, Southwestern Puerto Rico, 1942–43

	Per cent of total farms reporting	Average value per farm (all farms)	Per cent of total value
Operator's house	77.9	559	2.2
Dairy barns	19.6	53	0.2
Milk house	7.9	11	0.1
Equipment sheds	18.3	31	0.1
Houses for "agregados"	70.8	262	1.0
Other buildings	36.2	438	1.7
Total buildings		1,354	5.3
Aqueduct and watering places	50.8	251	1.0
Land	100.0	19,504	75.9
Total real estate		21,109	82.2
Livestock	94.6	2,147	8.4
Machinery	26.7	1,803	7.0
Equipment	88.3	599	2.3
Supplies	11.7	11	0.1
Other	0.1	6	*
Total		25,675	100.0

* Less than 0.1 per cent.

essential for the transportation of sugar cane from the field to railroad lines or to the places where it is picked up by trucks.

Use of the Land

Of the total acreage of the farms studied, 135 cuerdas, or 89 per cent, were classified as arable (table 14). The net area under cultivation amounted to a total of 62 cuerdas per farm, representing 40 per cent of the total land area.

The area in pasture, including aftermath, seeded pasture, clear per-

TABLE 13. INVESTMENT IN MACHINERY AND EQUIPMENT

240 farms, Southwestern Puerto Rico, 1942–43

Item	Farms reporting	Total Investment: Per farm reporting	Total Investment: All farms: Amount	Total Investment: All farms: Per cent of total
		$	$	
Machinery				
Trucks	14	2,001	117	4.9
Tractors	16	4,962	331	13.8
Irrigation equipment	13	23,602	1,278	53.2
Other*			77	3.2
Total			1,803	75.1
Equipment				
Dairy	51	56	12	0.5
Other	211	667	587	24.4
Total			599	24.9
Grand total			2,402	100.0

* Automobiles not included.

TABLE 14. USE OF THE LAND

240 farms, Southwestern Puerto Rico, 1942–43

Item	Cuerdas per farm	Per cent of total	Net cuerdas per farm (year basis)	Per cent of total
Total area cropped	74		56	
Minus:				
Intercropped	10		4	
Doublecropped	2			
Net area cropped	62	40	52	34
Aftermath			6	4
Seeded pasture	11	8	12	8
Clear permanent pasture	56	36	58	38
Wooded pasture	11	8	12	8
Woodland	3	2	3	2
Waste land	5	3	5	3
Buildings, roads and fences	5	3	5	3
Total	153	100	153	100
Area of arable land	135	89		

manent pasture and wooded pasture, amounted to 78 cuerdas per farm. This was 52 per cent of the total. Clear permanent pasture alone oc-

cupied an average of 56 cuerdas and represented 36 per cent of the total farm area. The rest of the land was in woods, waste, buildings, roads and fences.

The continuous growing season which is typical of the tropics makes possible in Puerto Rico the utilization of the same area of cropland for more than one crop during the year. In Southwestern Puerto Rico, in spite of the fact that there is a relatively long dry season and that the major enterprise is sugar cane which is a year crop, intercropping and

TABLE 15. DISTRIBUTION OF AVAILABLE PASTURE

240 farms, Southwestern Puerto Rico, 1942–43

Item	Farms reporting	Average per farm	Per cen of total
		cuerdas	
Harvested pasture			
Intercropped, net equivalent	1	*	—
Alone	27	0.2	0.2
Total	....	0.2	0.2
Seeded pasture			
Intercropped, net equivalent	1	†	....
Alone	78	12.5	15.6
Total	...	12.5	15.6
Permanent pasture			
Intercropped, net equivalent†	12	0.7	0.8
Aftermath, net equivalent	206	2.9	3.7
Wooded pasture, net equivalent	82	5.8	7.2
Alone	195	58.1	72.5
Total		67.5	84.2
Total available pasture	231	80.2	100.0
Area pastured per animal unit‡		2.9	

* Less than 0.05 cuerdas.

† In cocoanut groves.

‡ An average of 27.4 animal units per farm were pastured.

doublecropping are practiced to some extent. The land which has been used for cotton or tobacco is usually planted immediately after it has been harvested to other minor crops such as corn, sweet potatoes, beans, etc. Also combinations of crops are generally planted together. A very common practice is to intercrop corn and beans and corn or beans in tobacco, cotton, or sugar cane. The extent to which these farming practices were carried on in the farms studied is shown in table 14, with 10 and 2 cuerdas of intercropped and doublecropped land respectively.

Because of the fact that intercropping and doublecropping practices

are followed and that the use of the same cuerda of land may change during the year, we attempted in table 14 to describe the use of the land on a net year basis. For instance, a cuerda of land which was in corn six months and the rest of the year studied was left as aftermath was counted as one half net cuerda in crop and one half cuerda in aftermath. The same procedure was followed with the different plots of land in each farm. The following were the results obtained:

The net area cropped was only 52 cuerdas per farm, constituting 34 per cent of the total. It represented a reduction of 10 cuerdas per farm as compared to the net area under cultivation as calculated by the previous general method. The ten cuerdas, on the average, were distributed as follows: 6 were left as aftermath; two were whifted to clear permanent pasture; one was abandoned as wooded pasture and the remaining one was planted in seeded pasture. This means that part of the land in crops was shifted to other uses within the year studied. The importance of this fact is of special interest when estimating the total available pasture during the year so as to arrive at a more exact figure on the carrying capacity of pastures (table 15).

Distribution of Available Pasture

The average acreage of available pasture per farm studied amounted to 80.2 cuerdas (table 15).

The term available pasture is used to mean all the pasture available on the farm including harvested, seeded, and permanent pasture. The acreage is expressed on a net year basis. In the case of intercropped pasture (whether harvested, seeded or permanent) as well as in the aftermath, the total net-year-acreage available was given half weight in calculating the total available pasture for the farm. In other words, two year-acres of intercropped pasture or of aftermath were considered to be equivalent to one net acre of available pasture. The net equivalent available wooded pasture was calculated in the same way with the only difference that its equivalence was asked of the farmers themselves. It was done in this way because the condition of the wooded pastures as to its usefulness for grazing livestock is something that varies considerably on each farm.

Permanent pasture constituted 84 per cent of the total available pasture. Seeded pasture ranked second in acreage with a total of 16 per cent. The amount of harvested pasture present was practically insignificant. We mean by seeded pasture that which is seeded, cultivated and grazed but never harvested; so as to differentiate it from the harvested pasture, which is seeded, cultivated, and harvested, but never grazed.

As will be shown later in table 19, an average net total of 27.4 animal

units were pastured per farm studied. Therefore, the carrying capacity of the available pasture amounted on the average to 2.9 acres per unit. This figure compares favorably with studies made in other areas of the Island.

Crops Grown

A wide variety of crops were grown in these farms in 1942–43 (table 16). Sugar cane was the crop with the largest acreage. An average of 42 cuerdas were grown which accounted for nearly six tenths of the total acreage in crops. Following sugar cane in importance, as measured by acreage planted, is corn with an average of 12 acres which represent a little less than one-fifth of the total. Cotton and cowpeas were next, averaging 7 and 6 per cent respectively. Other crops grown were dry beans, cocoanuts, pigeon peas, sweet potatoes, tobacco, cassava, pineapples and harvested pastures. None of these crops amounted on the average to more than 2 cuerdas per farm.

TABLE 16. CROPS GROWN

240 farms, Southwestern Puerto Rico, 1942–43

Crop	Cuerdas grown per farm				Per cent of total
	Net	Inter-cropped	Double-cropped	Total	
Sugar cane	41.8	0.5	*	42.2	57.4
Corn	8.6	0.8	3.0	12.4	17.0
Cotton	4.9	*	—	5.0	6.8
Cowpeas	0.7	0.1	3.2	4.0	5.5
Dry beans	0.8	0.1	0.6	1.5	2.0
Cocoanuts	1.4	—	—	1.4	1.9
Pigeon peas	0.8	0.3	0.2	1.3	1.8
Sweet potatoes	0.7	0.1	0.2	1.0	1.4
Tobacco	0.3	0.1	—	0.4	0.5
Cassava	0.3	0.1	*	0.4	0.5
Pineapples	0.2	—	—	0.2	0.2
Harvested pasture	0.2	*	*	0.2	0.2
Other	0.9	0.1	2.5	3.5	4.8
Total	61.6	2.2	9.7	73.5	100.0
Harvested	56.1	0.9	8.0	65.0	88.5

* Less than 0.1 cuerda.

A total of 74 cuerdas of crops were grown per farm, out of which 65 cuerdas or 88 per cent of the total were harvested during 1942–43. An average of 56 cuerdas out of the 65 harvested were net, and only 8 cuerdas were intercropped. Double crops were of minor importance.

To summarize the crops grown on the farms studied during 1942–43, table 17 has been prepared.

An average of 74 cuerdas in crops per farm were grown. Of this 65 cuerdas or 88 per cent of the total were harvested. The remaining 9 cuerdas or 12 per cent were crops standing or crop losses. Inter and double-cropping practices were followed but to a lesser extent. Of the two practices, that of intercropping is more common as indicated by the fact

TABLE 17. SUMMARY OF CROPS GROWN
240 farms, Southwestern Puerto Rico, 1942–43

Item	Average per farm	Per cent of total
	cuerdas	
Area harvested		
Net	56	76
Doublecropped	1	1
Intercropped	8	11
Total	65	88
Standing crops and others*		
Net	6	8
Doublecropped	1	2
Intercropped	2	2
Total	9	12
Totals:		
Net	62	84
Doublecropped	2	3
Intercropped	10	13
Total area in crops	74	100

* Included 2 cuerdas of crop losses.

that 13 per cent of the total crops grown on each farm, on the average, were intercropped. On the other hand, only 3 per cent were doublecropped.

Crop Yields

The yields of crops grown on these farms were relatively satisfactory for most of the crops, if compared with the production per cuerda of the same crops in Puerto Rico as a whole. Yet, most of these yields, especially those of the minor crops, are much lower than those obtained on farms previously studied in other sections of the Island. These relatively lower yields may be partly explained because of the fact that the year of the

study, 1942–43, was a war year and the amount of fertilizer applied was necessarily reduced to war-time restrictions. Furthermore, it should be remembered that the area under study is one of the driest sections of the Island (table 18).

Sugar cane yields averaged 23.4 tons of cane and 2.99 tons of sugar per cuerda. The sucrose content, though not the tonnage, compares favorably with other areas.

The yields per cuerda of corn, 7.25 cwt., was relatively good, though much lower than those obtained in experimental trials.

Cotton yields, 4.52 cwt. per cuerda, were lower on the average, than those obtained by the Northwestern growers.

TABLE 18. CROP YIELDS

240 farms, Southwestern Puerto Rico, 1942–43

Crop	Unit	Yield per cuerda Alone	Yield per cuerda Inter-cropped	Total
Sugar cane	Tons-cane	23.40	—	23.40
Sugar cane	Tons-sugar	2.99	—	2.99
Corn	Cwt.	7.96	4.94	7.25
Cotton	Cwt.	4.52	—	4.52
Cowpeas	Cwt.	1.95	0.88	1.11
Dry beans	Cwt.	1.58	1.02	1.36
Cocoanuts	Thousands	0.97	·	0.97
Pigeon peas	Cwt.	3.17	2.00	3.01
Sweet potatoes	Cwt.	19.42	11.06	18.03
Tobacco	Cwt.	4.08	···	4.08
Cassava	Cwt.	23.40	36.86	24.47
Pineapples	Cwt.	132.55	··	132.55

Tobacco produced 4.08 cwt. per cuerda, which is far lower than the yields obtained in the tobacco area. The type of tobacco grown should be taken into consideration in measuring the significance of yields. In this area, the tobacco grown is mostly for chewing purposes, which is necessarily a lower yielder.

Pineapples produced 132.6 cwt. per cuerda. This relatively good yield may be partly accounted for by the fact that the soil where this crop is grown in the area is very well adapted.

Cocoanuts produced around one thousand nuts per cuerda. This yield is unsatisfactory as compared to the yields obtained in other cocoanut area of the Island.

The yields of the other crops grown, such as pigeon peas, cowpeas, sweet potatoes, dry beans, cassava and others are likewise considered unsatisfactory.

No comparison is here made with normal yields in the area because reliable information was not available.

Livestock

The average number per farm of the most important animals kept on the farms studied is shown in table 19. Averages were rounded up to the nearest figure.

TABLE 19. AVERAGE NUMBER PER FARM OF THE MOST IMPORTANT ANIMALS

240 farms, Southwestern Puerto Rico, 1942–43

Type	Average number (all farms
Cows	11
Heifers	4
Calves	7
Bulls	1
Oxen	7
Horses	1
Mares	1
Goats	1
Sows	1
Small pigs	1
Hens and roosters	19
Chickens	15
Turkeys	1

The farms studied reported having, on the average, a total of 11 cows, 4 heifers, 7 calves and 1 bull. The workstock kept was mostly oxen which amounted to an average of 7 per farm. In addition, each farm had one horse and one mare. Most of the farmers kept goats but, on the average, only one goat was reported per farm. The greatest majority of the farmers reported having also swine and poultry livestock. On the average, each farm had one sow, one small pig, 19 hens, 15 chickens and one turkey.

In terms of animals units,[6] dairy cattle was the most important group of livestock on the farms studied. It averaged 18.1 units per farm and accounted for about two-thirds of the total units of livestock present (table 20).

[6] A measure of the average number of animals kept on a farm during a year, based on the amount of feed consumed and value of manure produced. A mature cow, 1 bull, 1 ox, 1 horse or mare, 1 mule, 2 head of young stock, 5 sows or hogs or 10 pigs, 7 goats or sheep. 50 turkeys, 100 hens or roosters and 300 chickens are each considered as one animal unit.

TABLE 20. UNITS AND VALUE OF LIVESTOCK, BY TYPES

240 farms, Southwestern Puerto Rico, 1942–43

Type	Animal Units		Value		
	Per farm	Per cent of total	Per head	Per farm	Per cent of total
			$	$	
Dairy livestock					
Cows	10.91*	—	84	919	42.8
Heifers	2.07	—	38	159	7.4
Calves	3.57	—	12	86	4.0
Sires	0.37	—	125	47	2.2
Bulls	1.19	—	35	83	3.9
Total	18.11	64.7		1,294	60.3
Work-stock					
Oxen	7.39†	—	95	677	31.5
Horses	0.55	—	66	37	1.7
Mares	0.67	—	44	30	1.4
Colts	0.07	—	26	4	0.2
Mules	0.40	—	114	45	2.1
Total	9.08	32.5		793	36.9
Goats and sheep	0.16	0.6	6	6	0.3
Total grazing livestock	27.35	97.8		2.093	97.5
Poultry livestock					
Hens and roosters	0.19	—	1	22	1.1
Chickens	0.05	—	‡	7	0.3
Turkeys	0.02	—	3	3	0.1
Total	0.26	0.9		32	1.5
Swine					
Sows and boars	0.22	—	13	15	0.7
Pigs	0.11	—	4	4	0.2
Total	0.33	1.2		19	0.9
Other	0.03	0.1		3	0.1
Grand total	27.97	100.0		2,147	100.0

* Includes 0.03 year-average cow-units pastured temporarily on the farm, but not considered for the investment in cows.

† Includes 0.24 year-average oxen-units pastured temporarily on the farm, but not considered for the investment in oxes.

‡ Less than $0.50.

Workstock was second in importance and averaged practically the remaining third of the total. Oxen are the most important kind of draft animal on these farms. They are used for plowing and fitting the fields but mostly for hauling the sugar cane out of the farm. Goats and sheep are other grazing animals found on a large number of farms but its relative importance is very insignificant. The total grazing livestock averaged 27.4 animal units per farm of 98 per cent of the total. It practically made all of the livestock present. Swine, like poultry and other kinds of livestock were of minor importance and altogether did not amount to one animal unit per farm. Each farm reported having, on the average, a total of 28 animal units.

The average value per farm of all the livestock on the farms studied amounted to $2,147. Dairy cattle, of which cows were the most important, made three fifths of the total investment. Dairy cows alone accounted for 43 per cent. Practically the remaining two fifths of the total value was represented by the workstock present. The average value of oxen, which is the most important kind of animal power, comprised almost one third of the total value. Measured also in terms of investment, other livestock present on the farms was considered to be rather insignificant.

The quality of livestock on the farms studied in Southwestern Puerto Rico is not very satisfactory as may be seen by the average value per head of stock. For instance, the average value of dairy cows was $84 per head which undoubtedly is by far below the value of a good dairy cow in Puerto Rico. Even oxen rate very low if compared with the workstock of the big cane plantations. In conclusion, very few of the dairy animals are purebred. Very little selection or improvement has been practiced or attempted. Pastures are poor and feeding is deficient. These facts suggest that some effort should be directed along the line of selection and management to improve the quality of actual stock and increase its productive capacity.

Expenses and Receipts

Farm Cash Expenses. The total general farm cash expenses averaged $4,540 per farm. Hired labor accounted for $3,166, machinery and equipment for $371, fertilizer and insecticides for $306, taxes for $297, livestock feed for $46, building and building repairs for $31, rented pasture for $8, and other miscellaneous expenses for the remaining $315 (table 21).

Labor was the outstanding item of expense on these farms. It accounted for seven-tenths of the total farm cash expenses. An average of $2,595 per farm was spent in hired day labor alone, which represented 57 per cent of the general farm cash expenses. Only 18 per cent of the farmers reported expenses on manager or overseer with an average of $221 for all the

TABLE 21. FARM CASH EXPENSES

240 farms, Southwestern Puerto Rico, 1942–43

Item	Per cent of all farms reporting	Average per farm (all farms)	Per cent of total
		$	
Hired labor			
Daily labor, total*	97	2,595	57.2
Manager or overseer	18	221	4.9
Weekly labor†	31	185	4.1
Labor insurance	58	154	3.3
Board	13	11	0.2
Total		3,166	69.7
Machinery and equipment			
Irrigation pumps, operation	5	114	2.5
Trucks:			
purchases	1	12	0.2
operation	7	62	1.4
Tractors:			
purchases	2	19	0.4
operation	7	49	1.1
Milk wagons:			
purchases	1	5	0.1
operation	7	23	0.5
Auto: farm share	15	26	0.6
Equipment:			
purchases	35	19	0.4
repairs	53	42	1.0
Total		371	8.2
Fertilizer and insecticides			
Fertilizer:			
sugar cane	59	295	6.5
other crops	5	4	0.1
Insecticides	35	7	0.1
Total		306	6.7
Taxes	90	297	6.5
Livestock feed:			
concentrates	21	39	0.9
other	9	7	0.2
Total		46	1.1

TABLE 21—*Continued*

Item	Per cent of all farms reporting	Average per farm (all farms)	Per cent of total
		$	
Buildings:			
new	2	10	0.2
repairs	15	21	0.5
Total		31	0.7
Rented pasture	10	8	0.2
Other expenses			
Equipment hired	72	183	4.0
Work animals hired	47	48	1.0
Fences:			
new	5	4	0.1
repairs	65	26	0.6
Seed purchased:			
sugar cane	8	6	0.1
other	45	9	0.2
Milking materials	8	8	0.2
Ropes and twine	78	6	0.1
Marketing farm produce	25	5	0.1
Drugs and disinfectants	45	4	0.1
Horse and ox shoeing	37	4	0.1
Other	31	12	0.3
Total		315	6.9
Grand total		4,540	100.0

* The average total number of wages per farm reporting amounted to $2,213, out of which $1,605 were for sugar cane.

† The average total number of weeks per farm reporting amounted to 152, out of which 60 were for sugar cane.

farms, constituting around 5 per cent of the farm cash expenses. Only the larger farms can afford to incur this expense. Thirty-one per cent of the farmers reported weekly labor. This item of expense amounted to $185 on the average for all farms and made a little over 4 per cent of the total farm cash expenses. The expenditure for labor insurance was reported in 58 per cent of the farms. It amounted to $154 per farm, on the average, or to over 3 per cent of all cash expenses. Board to laborers is a rather insignificant expenditure but is important from the point of view of the few farmers who incurred that type of expense. Mostly smaller farmers continue this practice and are mainly those whose major enterprise is other

than sugar cane. This can be described as a "cultural hang-over" which has been disappearing little by little with the gradual appearance of our present system of commercial farming.

Machinery and equipment ranked second to labor in importance among the general farm cash expenses, with an average of 8 per cent of the total. Of this the most important single expenditure was that of the operation of irrigation pumps. Although only 5 per cent of the farmers reported this expenditure, it amounted to an average of $114 per farm for all farms, and made 2.5 per cent of all cash expenditures. The other single item of machinery and equipment expenses are of minor consideration.

Fertilizer and insecticides expenses followed in importance, accounting for 6.7 per cent of all farm cash expenses. Most of the fertilizer was applied to sugar cane which alone made for 6.5 per cent of the total farm cash expenses. Very few farmers reported buying fertilizer for other crops. The insecticides purchased were mostly Paris Green, wheat flour, lead arsenate, and hydrated lime. These were purchased mostly by the farmers growing cotton and/or tobacco.

Among all other items of expenditure it is important to point out that of rented pasture, not for the amount that it represents, but for its significance considering the great scarcity of pasture in the area during the prolonged dry season. Only 10 per cent of the farms studied reported this expenditure which amounted to the very insignificant amount of $8 per farm during the year. The bigger land holders are the only ones who can afford to rent pasture. However, smaller farmers seem to manage themselves well enough to feed their livestock, probably by grazing it on free pastures provided by surrounding big land-holders or by feeding cane tops during the harvesting months. Surprisingly, in spite of the alleged seriousness of this problem of pastures, no attempt has been made so far by either the farmers or the agricultural agencies of the Island to explore the possibilities of solving this problem with practices such as growing hay pastures or maintaining silos for the season. Apparently the problem has not been serious enough, from the economic standpoint, to stimulate the farmers or the agencies to work for its definite solution.

Crop Sales. Crop sales amounted to $5,507 per farm studied (table 22). Sugar cane is the outstanding enterprise. It constituted the most important source of income as indicated by the fact that it accounted for nearly nine-tenths of the total crop sales and averaged $4,768 per farm. The price paid to farmers per ton of sugar cane delivered was $5.47. This price includes only the average amount of money received by the farmer from the sugar mill per ton of sugar cane delivered. It does not include the deduction which, according to the grinding contract, is made by the

sugar mill for the processing of the sugar cane; nor does it include A.A.A. and rebated transportation payments made to the growers.

No other individual crop, aside from sugar cane, stood out as particularly important, on a commercial scale, for all the farms. Corn and cotton were second in importance, averaging each around $260 per farm and representing 5 per cent each of the total sales of crops. The receipts from tobacco, which ranked third, contributed $110 per farm, or 2 per cent of the total crop sales.

The average value per farm of the sales of most of the crops was very low. For instance, sales of cocoanuts, sweet potatoes, pineapples, cowpeas,

TABLE 22. CROP SALES

240 farms, Southwestern Puerto Rico, 1942–43

Crop	Unit	Amount sold per farm	Price per unit	Sales	
				Per farm	Per cent of total
			$	$	
Sugar	Tons	872.4	5.47	4,768	88.6
Corn	Cwt.	72.5	3.60	261	4.7
Cotton	Cwt.	22.3	11.57	258	4.7
Tobacco	Cwt.	1.4	81.48	110	2.0
Cocoanuts	Thousands	1.4	20.61	28	0.5
Sweet potatoes	Cwt.	9.6	1.76	17	0.3
Pineapples	Cwt.	10.1	1.54	16	0.3
Cowpeas	Cwt.	1.7	6.59	11	0.2
Pigeon peas	Cwt.	1.3	6.23	8	0.1
Dry beans	Cwt.	0.9	8.43	8	0.1
Cassava	Cwt.	2.3	1.54	3	0.1
Other	—	—	—	19	0.4
Total				5,507	100.0

pigeon peas, dry beans, cassava and other crops, made only 2 per cent of the total receipts from sales of crops. They may have constituted important source of income for a few individual farms, but not for all farms as a whole. Most of these minor crops are grown for home use, and only a few farms sell part of their production, especially those harvesting considerable quantities above their consumption needs.

Prices received by the farmers studied in 1942–43 were neither low nor too high. They can be better described as slightly high, in general. Tobacco prices seem to be exceptionally high, with an average price reported of $81.48 per hundredweight. It should be remembered, though, that this is chewing tobacco which is processed at the farm. The price

reported is that received by the farmer at the farm for the processed product.

Livestock Products. The total value of all livestock products on the farms studied averaged $845 per farm. Sales represented three-fourths of their total and almost one-fifth was used by the operator's family. The remaining part was given away to "agregados" and others (table 23).

Milk was the most important livestock product. Its sales averaged 6,722 quarts per farm with a total value of $615. The family used an average of 1,381 quarts and a total of 32 quarts per farm were given away. Total milk production on these farms averaged 8,639 quarts and amounted to $798 per farm.

TABLE 23. LIVESTOCK PRODUCTS

240 farms, Southwestern Puerto Rico, 1942–43

Product	Sold		Used by family		Given away		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
		$		$		$		$
			Average per farm					
Milk, quarts	6,722	615	1,381	132	536	51	8,639	798
Eggs, dozens	29	12	62	27	9	4	100	43
Other		3		1		*		4
Total		630		160		55		845
Per cent		75		19		6		100

* Less than $0.50.

Eggs were the only other important livestock product. An average of 100 dozen were produced per farm, out of which 29 were sold, 62 used by the family and the rest were given away. The total average value of egg sales per farm amounted to $12; those used by the family to $27 and an average value of $4 was given away. The total value of eggs produced per farm amounted to $43 per farm, on the average.

Farm Privileges. The farm privileges include the value of products from the farm used for home consumption and those given away, plus the rental value of the operator's dwelling. On the farms studied they amounted to an average of $456 per farm (table 24).

Livestock products, which averaged $215 per farm and represented almost one-half of the total, accounted for the major proportion of the farm privileges. The yearly rental value of the operator's dwelling with $118 per farm was second in importance, representing a little over one-fourth of the total value of farm privileges. Crops privileges averaged

$60 or 14 per cent of the total, livestock $31 or 7 per cent, and wood averaged $20 accounting for only 4 per cent of all farm privileges. The value

TABLE 24. FARM PRIVILEGES

240 farms, Southwestern Puerto Rico, 1942–43

Item	Average value per farm	Per cent of total
	$	
Livestock products*	215	47
Rent value of dwelling	118	26
Crops*	60	14
Livestock	31	7
Wood	20	4
Charcoal	6	1
Other	6	1
Total	456	100

* Includes livestock products and crops given away.

TABLE 25. MISCELLANEOUS RECEIPTS

240 farms, Southwestern Puerto Rico, 1942–43

	Per cent of all farms reporting	Average per farm (all farms)	Per cent of total
		$	
Benefit payments:			
Sugar	78	1,482	84.9
Other	69	30	1.7
Sugar cane transportation rebates	67	123	7.1
Machinery and equipment hired	9	51	2.9
Custom grazing	6	20	1.1
Labor off farm	9	13	0.7
Work animals hired	11	10	0.6
Charcoal sold	5	5	0.3
Lumber and wood sold	4	4	0.2
Rent of farm buildings	6	4	0.2
Seed sold	3	1	0.1
Other	8	3	0.2
Total		1,746	100.0

of charcoal and other farm privileges represented insignificant amounts, each one accounting for only one per cent of the total.

Miscellaneous Receipts. Besides the receipts from crop sales and livestock and livestock products sold, the farmers of the Lajas Valley studied had some additional income from other miscellaneous sources connected

with the farm business. The total for these miscellaneous receipts amounted to an average of $1,746 per farm (table 25). Most of the miscellaneous receipts came directly from sugar cane. The benefit payments made by the Agricultural Adjustment Administration were by far the outstanding item among the miscellaneous receipts. These payments amounted to an average of $1,482 per farm or nearly 85 per cent of the total. If to this amount are added the payments made to sugar cane growers by the sugar mill for sugar cane transportation rebates, which amounted to $123 on the average and which constituted 7 per cent of the total, then the miscellaneous receipts derived from the sugar cane enterprise represented alone over nine-tenths of the total miscellaneous receipts.

Of all the other miscellaneous items of receipts only those of machinery and equipment hired, soil conservation payments and custom grazing are worth mentioning. Although only 9 per cent of the farmers—the larger ones—reported hiring machinery and equipment, this item accounted for nearly 3 per cent of all miscellaneous receipts. Soil conservation payments made to farmers as compensation for the adoption of certain farm practices, accounted for about 2 per cent of the total. Custom grazing, that is, renting pasture, to outsiders, accounted for the insignificant amount of one per cent of the total miscellaneous receipts. All other items together, such as labor off farm, work animals hired, sales of charcoal, lumber and wood, rent of farm buildings, sales of seed and other amounted together on the average to $40 per farm and represented only 2.6 per cent of the total miscellaneous receipts.

Summary of Expenses and Returns. A brief summary of the general aspects of the farm organization and an insight into the financial returns of the farms studied is presented in table 26.

The average total receipts amounted to $8,212 per farm. A little over two-thirds came from crop sales, 8 per cent from livestock products sold, 3 per cent from livestock sold, 21 per cent from miscellaneous receipts and only 1 per cent came from a net increase in the inventory of the farm during the year. This net increase in inventory is also a part of the total receipts.

It is definitely established here that Southwestern Puerto Rico is not mainly a livestock area as is the impression of many people in the Island. It is primarily a sugar cane region.

The total farm expenses averaged $4,676 per farm. The general farm cash expenses accounted for the greater bulk of the total expenses, representing 98 per cent of them. Livestock bought during the year accounted for one per cent. The value of the unpaid family labor is also considered as an expense in the farm and it made only one per cent of the total farm expenditures.

The average total receipts exceeded the average total expenses on these

TABLE 26. SUMMARY OF EXPENSES AND RETURNS

240 farms, Southwestern Puerto Rico, 1942–43

Item	Total: Average per farm	Total: Per cent of total
Receipts:		
Crop sales	$5,507	67
Livestock products sold	630	8
Livestock sold	273	3
Miscellaneous receipts	1,746	21
Net increase in inventory	56	1
Total receipts	$8,212	100
Expenses:		
Farm cash expenses	$4,540	98
Livestock bought	60	1
Unpaid family labor	74	1
Unpaid animal and machine work	2	
Total expenses	$4,676	100
Farm income	$3,536	
Interest on capital	1,540	
Labor income	$1,996	
Farm privileges	456	
Labor earnings	$2,452	
Value of operator's time	$453	
Return on capital	$3,083	
Capital invested	$25,675	
Per cent return on capital	12.0	
Capital turnover	3.1	
Net farm cash income	$3,556	
Return on labor	$5,692	
Man equivalent	7.7	
Return on labor per man	$738	

farms by $3,536. This balance represents the farm income, or the amount which the farmer received for his year's work, and the use of the capital invested. In order to put all farms on a comparable basis, regardless of capital investment, 6 per cent interest on the average capital invested was

deducted from the farm income to obtain the labor income. Therefore, labor income represents what the farmer received for a year's labor and management. In addition, the operator usually lives in the farm house and uses crops, livestock, and other products of the farm in his home. These last items are not considered in the determination of labor income.

The average total labor income per farm was $1,996. This means that the average total receipts of these farms were enough to pay the total farm expenses and to cover the interest on the average capital invested, and that the farmer received $1,996 for his year's work. The labor earnings of these farms, which are obtained by adding the $456 of farm privileges to the labor income, amounted to $2,452. Labor earnings is a very reliable measure of profitableness in a farm; however, its use is limited by the fact that it is very difficult to estimate with great accuracy the privileges of the farm. For this reason, labor income is many times preferred as a measure of farm profits.

The farm income minus the value of the operator's time, as estimated by the farmer himself, gives the return on capital. The farm income represents, as already explained, the income from capital and operator's labor. The average value of the operator's time for these farms was estimated as $453. This amount, subtracted from the total average farm income ($3,536) gives the return on capital, which averaged $3,083.

The return on capital, expressed as a percentage of the average capital invested ($25,675) gives the per cent return on capital. These farms had a per cent return on capital of 12 per cent. The per cent return on capital is an important measure of success from the standpoint of the person who contributes the capital. Where land is a limiting factor, as in Puerto Rico, because of its scarcity, or because of its high value, the per cent return on capital is of particular importance as well.

The capital turnover measures the time in years that it takes the farm receipts to equal the capital invested. Dividing the average capital (25,675) by the average total receipts (8,212) we found the capital turnover of these farms, which was 3.1 years.

If we add the farm cash receipts and from them subtract the sum of all cash expenses, we get the net farm cash income. For the farms studied, the net farm cash income was $3,556. This represents the amount on which the farmer can draw to meet his family cash expenses, and to pay his debts and the interest on any mortgage with which the farm may be encumbered. It is obvious that with the net cash income they obtained the farmers in general were in very good shape in the year studied.

The labor earnings plus the value of the unpaid family labor plus the cash labor expenses gives the return on labor. For the farms studied it averaged $5,692 per farm. This measure of return is of more significance

if it is expressed in terms of the men employed on the farm; that is, return on labor per man equivalent. It is not only of interest from the economic point of view, but to some extent from the social point of view as well. The reason is that it is a rough indication of the amount of money upon which each man employed on the farm, on the average, can rely for his or his family's living. Therefore, it is consequently a rough indication of their average standard of living. With an average man equivalent of 7.7 men per farm, these farms provided a $738 return on labor per man in the year 1942-43. This amount is considered by other farms studied in other sections of the Island.

FACTORS AFFECTING FARM EARNINGS

The analysis of the factors influencing farm earnings is one of the main objectives of the farm management study undertaken in the Lajas Valley area. It has been found that returns from farming vary considerably from farm to farm, within a given group. It is therefore important to find the reasons for these variations.

The labor income, as has been already stated, is preferred to others as a measure for the profitableness of a farm. The earnings of a farm are generally expressed in terms of labor income. However, a high labor income may not always be an entirely dependable index of proficiency in farming. Earnings may have been very high under the most favorable conditions and, conversely, they may have been too low to be profitable, even for the best farms, when conditions have been remarkably unfavorable. The ability of a farm to pay better than other farms of similar characteristics and under similar conditions which make the aggregate of the region, may be a pretty good indication of its relative efficiency, although not of its general success as a business enterprise. Therefore, comparisons have to be established to find out why, under a given set of conditions, some farms are more successful than others.

The farmers investigated in the Lajas Valley have different interests in farming. The smaller in size (and this group constituted the great majority) are more concerned with what they get from the farms for their own time. The remaining few but larger farmers, on the contrary, are more interested in what they obtain as returns for the use of the capital invested. For this reason, other measures of profitableness besides labor income and labor earnings are used wherever possible, to measure the variation in success on these farms; namely, return on capital, per cent return on capital and capital turnover.

Differences in earnings between individual farms, or between representative groups of farms, may be explained by their comparative rating in certain factors, as of size, intensity of land use, labor efficiency, rates of

production, combination of enterprises, farm mechanization, and other upon which the profits of farming generally depend. The most renumerative business set-up is the one which excels in more of the important factors, or which best combines a number of them to a greater advantage.

An attempt has been made to discuss in this section some of the factors which affected the financial returns of the farms studied in Southwestern Puerto Rico, for the crop year 1942–43. In order to establish the existing relationships, the farms have been divided into groups according to their standing in the individual factors considered.

Relation of Size of Business to Farm Earnings and Other Factors

A farm enterprise needs sufficient size of business in order to be profitable. As a rule, the larger farms make the better profits because of their advantage over small farms of being able to use more efficiently the factors of production and marketing. However, this is true within certain limits since there are certain circumstances under which this relationship does not work. Unfavorable years, for instance, may cause the most serious drawbacks to profits in farming. When the weather conditions have been very poor, or prices very low, it is very likely that the farms which developed the greatest activities have the largest losses. Furthermore, beyond a certain top limit of size, labor is less efficiently used and therefore in situations of very expensive labor, large farms cannot compete advantageously. In appraising the effects on earnings of the factors determining size of business, these considerations have to be kept in mind.

Several measures of size of business were related to earnings and other factors; namely, total capital invested, total cuerdas in farm, cuerdas in sugar cane, tons of sugar cane harvested, and man equivalent. The main reason for using more than one size factor was to observe consistencies or variations in the relationships found. The results found are presented in the pages to follow.

Total Capital Invested

Capital invested is a very good measure of the size of the farms in the area. Its relationship to farm earnings and other factors is shown in tables 27 to 36 presented below.

Other Size Factors. The relationship of total capital invested to other size factors is demonstrated in table 27.

The total cuerdas in farm as well as the net cuerdas harvested increased definitely with increases in the capital invested. The same relationship was observed as to the cuerdas and the tons of sugar cane harvested, however, the differences in tons of sugar cane produced can be described as substantially high. On the contrary, although the acreage in tobacco, cotton and corn was also found to increase in direct relationship with the

capital invested, the increases were not as significant. The number of men employed in the farms studied, as measured by man equivalent, increased directly with capital. The investment in machinery and equipment showed very significant increases with increases in farm capital, especially in the largest group of farms.

TABLE 27. RELATION OF TOTAL CAPITAL INVESTED TO OTHER SIZE FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Total capital invested: Range	Total capital invested: Average	Number of farms	Total cuerdas in farm	Net cuerdas harvested	Cuerdas in cane harvested	Tons of cane harvested	Cuerdas in tobacco, cotton and corn	Man equivalent	Investment in machinery and equipment
$	$								$
Less than 1,500	1,046	24	10	6	2.9	54	4.4	1.4	32
1,500– 2,499	1,911	47	13	8	5.5	93	2.4	1.8	39
2,500– 4,999	3,582	38	23	13	7.8	120	5.4	2.4	82
5,000– 9,999	6,989	44	46	25	13.6	243	11.6	3.3	300
10,000–19,999	14,283	40	102	49	24.4	448	28.6	5.8	488
20,000–39,999	28,552	25	174	83	48.3	845	32.1	8.8	879
40,000 and over	196,286	22	1,109	330	252.0	6,791	56.0	47.6	23,453

TABLE 28. RELATION OF TOTAL CAPITAL INVESTED TO INTENSITY OF LAND USE AND OTHER FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Total capital invested: Range	Total capital invested: Average	Number of farms	Economic land class	Per cent land arable	Per cent of arable land harvested	Per cent net harvested land in cane	Per cent total harvested land in tobacco, cotton and corn	Equipment investment per cuerda harvested
$	$							$
Less than 1,500	1,046	24	4.3	89	72	46	48	5
1,500– 2,499	1,911	47	3.6	93	66	67	23	5
2,500– 4,999	3,582	38	3.6	89	63	60	32	6
5,000– 9,999	6,989	44	3.7	93	59	53	35	12
10,000–19,999	14,283	40	3.7	91	53	49	44	10
20,000–39,999	28,552	25	3.7	92	52	58	33	11
40,000 and over	196,286	22	2.5	87	34	76	16	71

To summarize, total capital invested was directly related to other size factors studied, although in varying degrees of significance.

Intensity of Land Use and Other Factors. The total investment of capital was also related to the intensity with which the land was used and various other factors. It is attempted in table 28 to describe the relationships found.

As stated in a previous section of this report, the intensity of land use in each farm studied was determined after completing the land classification of the area. For the purpose of the study of relationships the average land class of each group of farms was calculated. This is probably not the best procedure to follow since the average land class is a very generalized concept; however, it serves the purpose of indicating to some extent the intensity of land use in each group of farms.

Although a very straight relationship was not found between capital invested and economic land class, it is definitely demonstrated that the largest farms are located on the best lands and that, conversely, the smallest farms are situated on the poorest lands. The per cent of arable land on the farms studied showed practically no variation with increases in capital. A smaller percentage of the arable land is cultivated on the larger farms. The larger farms showed also higher percentages of the net area harvested planted to sugar cane. On the contrary, the percentages planted to other less important crops in the area, such as tobacco, cotton and corn, decreased with increases in the size of the farm, as measured by total capital invested. This fact shows very convincingly that the degree of specialization increased as the size of the farm business increased and that, on the other hand, diversification was greater on smaller farms. This higher specialization permitted these farms to mechanize to a larger extent as is shown in this table in which a direct relationship was observed between the investment in machinery and equipment per net cuerda harvested and farm capital. The most significant increase is that which occurred between the last two groups of farms, that is, from $11 to $71 per cuerda.

TABLE 29. RELATION OF TOTAL CAPITAL INVESTED TO LIVESTOCK

240 farms, Southwestern Puerto Rico, 1942–43

Total capital invested: Range	Total capital invested: Average	Number of farms	Total animal units	Per cent grazing units	Per cent productive units	Per cent cow units is of productive units	Per cent investment in livestock	Average value per productive unit
$	$							$
Less than 1,500	1,046	24	3.0	86	64	53	18	59
1,500– 2,499	1,911	47	3.2	89	75	54	11	65
2,500– 4,999	3,582	38	7.0	90	66	56	13	62
5,000– 9,999	6,989	44	10.1	94	65	59	11	74
10,000–19,999	14,283	40	17.6	95	58	57	10	77
20,000–39,999	28,552	25	30.2	99	63	66	8	72
40,000 and over	196,286	22	196.3	99	63	63	8	72

Livestock. The relationship of the total capital invested to the livestock kept on the farm is shown in table 29.

The total animal units kept on the farm were found to increase with increases in size as measured by total farm capital. The per cent constituted by the grazing livestock was also found to be in direct relationship with capital investments. However, the per cent of the total livestock classified as productive did not show any significant variations. By productive livestock it is meant all the livestock of the farm excluding only the work stock. So, the relative number of work stock as well as that of productive livestock on the farms studied remained rather constant, regardless of size. The proportion of productive animal units made by dairy-cows varied in direct relationship with capital. In other words, the farms with larger capital investments had a higher proportion of dairy-cow units. A straight relationship between the per cent investment

TABLE 30. RELATION OF TOTAL CAPITAL INVESTED TO USE OF PASTURE LAND

240 farms, Southwestern Puerto Rico, 1942–43

Total capital invested		Number of farms	Cuerdas in available pasture				Cuerdas in clear permanent pasture	
Range	Average		Total	Per grazing live-stock unit	Per cent of total cuerdas in farm	Per cent of total arable land	Total	Per cent of avail-able pasture
$	$							
Less than 1,500	1,046	24	3	1.2	30	34	3	100
1,500– 2,499	1,911	47	4	1.4	29	32	4	100
2,500– 4,999	3,582	38	8	1.3	36	41	7	88
5,000– 9,999	6,989	44	19	2.0	41	45	16	86
10,000–19,999	14,283	40	42	2.5	41	46	32	76
20,000–39,999	28,552	25	81	2.7	46	50	73	91
40,000 and over	196,286	22	642	3.3	58	66	540	84

in livestock and farm capital was not observed. However, there exists a tendency for it to decrease with increases in capital investment. The average value per productive animal unit on the farm was in direct relationship with the total capital invested. This indicates the fact that the larger sized farms had better quality livestock than the smaller farms. It is obvious that they could afford to buy better animals.

Use of Pasture Land. We attempted to discover any relationship that may exist between total capital invested and pastures and use of pasture lands. Findings are shown in table 30.

The total number of cuerdas in available pasture, increased as the farm capital increased. The larger farms reported having more cuerdas in available pasture per grazing livestock unit. The larger sized farms also reported having a higher proportion of the total cuerdas in the farm, as well as a higher percentage of the total arable land, devoted to pastures.

The amount of permanent pasture alone was larger for the farms with larger capital investments. The per cent that it constituted of the total available pasture, however, showed a tendency to decrease with increases in size. This is very interesting, since it indicates that the larger farms have improved their pastures to some extent by having very probably a higher proportion of their total available pasture in seeded and harvested pastures.

Irrigation. The relation of total capital invested to irrigation in the area is something of much interest to observe. Table 31 presents the relationships found.

It is definitely demonstrated here that irrigation is practiced by the very few largest farms in the area. The smaller farms reported having no

TABLE 31. RELATION OF TOTAL CAPITAL INVESTED TO IRRIGATION

240 farms, Southwestern Puerto Rico, 1942-43

Total capital invested			Investment in irrigation equipment				Cuerdas of sugar cane irrigated		
Range	Average	Number of farms	Total	Per cuerda of cane harvested	Per cuerda of cane irrigated	Per cent of total capital	Total	Per cent of total arable land	Per cent of cane harvested
	$		$	$					
Less than 1,500..	1,046	24	0	0	0	0	0.0	0.0	0.0
1,500- 2,499....	1,911	47	0	0	0	0	0.0	0.0	0.0
2,500- 4,999....	3,582	38	0	0	0	0	0.0	0.0	0.0
5,000- 9,999...	6,989	44	0	0	0	0	0.2*	0.5	1.7
10,000-19,999....	14,283	40	74	3	53	1	1.4	1.5	5.7
20,000-39,999....	28,552	25	0	0	0	0	0.0	0.0	0.0
40,000 and over..	196,286	22	13,811	55	94	7	146.6	15.2	58.2

* Irrigated with outside equipment

investment at all in irrigation equipment. Some of the farms in the group ranging in capital from $5,000 to $10,000 reported some sugar cane lands irrigated, but it was done with outside equipment. A few farms in the group, ranging from $10,000 to $20,000 in capital investment, were the first to report irrigation equipment. Practically all the irrigation equipment of the area studied belongs to those farmers who reported a capital investment of $40,000 or over. Consequently, nearly all the sugar cane lands irrigated were the property of these farmers, too.

Rates of Production and Labor Efficiency. Definite relationships were found between the rates of production and labor efficiency as measured by several different factors, and size of farm as measured by capital invested (table 32).

The larger farms had higher rates of production as shown by a higher

tonnage of sugar cane per cuerda and more quarts of milk produced per cow unit. As to the crop index (excluding sugar cane), the smaller farms showed a tendency to have higher yields. The crop index, as calculated, included only the crops which on the average are considered of secondary importance in the area. The larger farms specialized more in sugar cane, as shown before, and paid very little attention to these minor crops. The main reason why they planted a few cuerdas of these crops was to comply with the requirements of the Agricultural Adjustment Administration in order to qualify for sugar cane benefit payments. Consequently, the yields obtained by these larger farms were on the average lower.

TABLE 32. RELATION OF TOTAL CAPITAL INVESTED TO RATES OF PRODUCTION AND LABOR EFFICIENCY

240 farms, Southwestern Puerto Rico, 1942–43

Total capital invested: Range	Total capital invested: Average	Number of farms	Crop index (excluding cane)	Tons of cane per cuerda	Quarts of milk per cow unit	Net cuerdas harvested per man	Cuerdas in cane harvested per man	Tons of cane per man	Capital invested per man	Return on labor per man	Gross income per man
$	$								$	$	$
Less than 1,500	1,046	24	105	19	708	4.4	2.0	37	723	489	518
1,500– 2,499	1,911	47	109	17	707	4.6	3.1	53	1,078	501	597
2,500– 4,999	3,582	38	115	15	763	5.4	3.3	50	1,501	542	635
5,000– 9,999	6,989	44	100	18	847	7.8	4.2	75	2,143	721	962
10,000–19,999	14,283	40	96	18	816	8.5	4.2	77	2,456	740	990
20,000–39,999	28,552	25	125	17	621	9.4	5.5	96	3,255	741	1,103
40,000 and over	196,286	22	92	27	820	6.9	5.3	143	4,124	783	1,238

The fact that they obtained more tons of sugar cane to the acre is easily explained. As demonstrated before, these farmers had the better lands and were the only ones who enjoyed the privilege of irrigating most of their cane lands. Furthermore, they applied to advantage more units of production per cuerda, as will be later shown.

In relation to the higher production of milk per cow, it happened somewhat similarly. These farms had not only more and better pastures but also better animals, and, very surely, they fed them better too.

The efficiency in the use of labor was definitely higher on the farms with larger capital investments. The larger farms reported more net cuerdas in crops harvested, and more cuerdas in sugar cane harvested per man. However, the largest group of farms, above $40,000 in capital invested, were below the maximum of efficiency as measured by these factors, showing a definite decline beyond certain limits. The larger farms, with

higher yields and a larger acreage in cane per man, produced more tons of sugar cane per man

The capital invested per man, which also indicates to some extent the efficiency in the use of capital, increased consistently with increases in size. Finally, the return on labor and the gross income per man were larger for the larger sized farms.

There is no doubt about the fact that the larger farms studied had higher rates of production both in crops and animals. They also used more efficiently the labor employed on the farm, but apparently up to a certain limit, beyond which it shows a tendency to decline.

Farm Expenses. Farm expenses were found to be directly related to size of farms, as measured by total capital invested (table 33).

TABLE 33. RELATION OF TOTAL CAPITAL INVESTED TO FARM EXPENSES

240 farms, Southwestern Puerto Rico, 1942–43

Total capital invested		Number of farms	Farm cash expenses			Hired labor expenses	
Range	Average		Total	Per total cuerda harvested	Per net cuerda harvested	Total	Per cent of total cash expenses
$	$		$	$	$	$	
Less than 1,500....	1,046	24	320	35	51	153	48
1,500– 2,499......	1,911	47	465	45	56	243	52
2,500– 4,999......	3,582	38	661	39	51	375	57
5,000– 9,999..	6,989	44	1,507	45	59	827	55
10,000–19,999......	14,283	40	2,770	43	56	1,741	63
20,000–39,999......	28,552	25	4,987	51	60	3,204	64
40,000 and over....	196,286	22	33,322	94	101	24,750	74

Obviously the total farm cash expenses increased with increases in farm capital. What is more significant is that the farm cash expenses per total cuerda harvested and per net cuerda harvested showed marked tendencies to increase in the same direction. The larger farms spent not only more money for hired labor but also this item of expense accounted for a larger percentage of the total farm cash expenditures. The apparent conclusion that could be drawn from the above facts is that the larger farms applied more units of production per cuerda, and that a larger proportion of the labor force on the smaller farms is accounted for by the unpaid labor available.

Farm Receipts. In table 34 it is attempted to present the relation of total capital invested to farm receipts.

The total farm gross income was, as is logical, larger for the larger sized farms, as measured by total capital invested. The per cent of the gross income accounted for by crop sales showed a tendency to increase with

increases in size; but the tendency is more marked in the case of the per cent of the income derived from sugar cane. Sugar cane acreage and tonnage, as previously shown, increased consistently with increases in size. The relative importance of the income from tobacco, cotton and corn tended to diminish as the size of the farms increased. This finding agrees with the previous fact shown that the acreage planted to these crops was also of less relative importance in the larger farms. Although no clear straight relationship was observed between the per cent of the income derived from livestock and livestock products with capital invested, the tendency is for the larger farms to have a larger percentage.

It is worth mentioning here that the per cent crop sales is of the total value of crops harvested increased directly with increases in farm capital.

TABLE 34. RELATION OF TOTAL CAPITAL INVESTED TO FARM RECEIPTS

240 farms, Southwestern Puerto Rico, 1942-43

Total capital invested: Range	Total capital invested: Average	Number of farms	Total farm gross income	Per cent income from crop sales	Per cent crop sales is of total crops value	Per cent income from cane	Per cent income from tobacco, cotton and corn	Per cent income from live-stock and products
$	$		$					
Less than 1,500	1,046	24	748	59	90	62	14	6
1,500- 2,499	1,911	47	1,058	60	92	73	9	8
2,500- 4,999	3,582	38	1,516	59	91	64	12	11
5,000- 9,999	6,989	44	3,138	61	96	63	16	9
10,000-19,999	14,283	40	5,778	65	97	63	19	8
20,000-39,999	28,552	25	9,679	63	98	69	11	9
40,000 and over	196,286	22	58,910	67	99	81	3	12

This shows that the smaller farmers consumed at the farm a larger share of the crops harvested. The larger farmers are not only more specialized in sugar cane growing, the crop of which is entirely sold, but also they sell, on the average, most of the crops grown.

Farm Earnings. In general, farm earnings as measured by different factors, increased with increases in the size of the farm, as measured by total capital invested (table 35).

The return on the capital invested was directly related to size, but no relationship was observed with the per cent return on capital. However, the farms ranging from $5,000 to $10,000 in total farm investments, had the highest per cent return on capital. Beyond this point it diminishes to a level for the largest farm slightly above that of the smallest ones. The capital turnover increased consistently with increases in the size of farm. A significant direct relationship was also found between size of

farm and return on labor, net farm cash income, labor income and labor earnings. Size of farms is, definitely, very closely associated with the profitableness and success of the farms of the Lajas Valley Area.

Farm Mortgage Indebtedness and Other Factors. Other miscellaneous factors, among which farm mortgage indebtedness was included, were also related with total capital invested (table 36).

TABLE 35. RELATION OF TOTAL CAPITAL INVESTED TO FARM EARNINGS

240 farms, Southwestern Puerto Rico, 1942–43

Total capital invested		Number of farms	Return on capital	Per cent return on capital	Capital turn-over	Return on labor	Net farm cash income	Labor income	Labor earnings
Range	Average								
$	$		$			$	$	$	$
Less than 1,500.	1,046	24	106	10.2	1.40	708	368	276	502
1,500– 2,499...	1,911	47	220	11.5	1.80	888	517	357	586
2,500– 4,999...	3,582	38	329	9.2	2.36	1,293	711	437	787
5,000– 9,999...	6,989	44	1,128	16.1	2.23	2,352	1,408	1,049	1,453
10,000–19,999...	14,283	40	2,292	16.0	2.48	4,304	2,677	1,859	2,442
20,000–39,999...	28,552	25	3,729	13.1	2.95	6,504	4,041	2,739	3,278
40,000 and over..	196.286	22	21.827	11.1	3.33	37,276	22,224	11,367	12,519

TABLE 36. RELATION OF TOTAL CAPITAL INVESTED TO FARM MORTGAGE INDEBTEDNESS AND OTHER FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Total capital invested		Number of farms	Age of operator	Farm population	Distance to nearest paved road (kms.)	Farm mortgage indebtedness		
Range	Average					Total	Per total cuerda in farm	Per cent of total capital
$	$					$	$	
Less than 1,500.	1,046	24	54	11	1.2	15	2	1
1,500– 2,499..	1,911	47	50	12	0.9	37	3	2
2,500– 4,999..	3,582	38	51	14	1.3	37	2	1
5,000– 9,999..	6,989	44	49	14	0.7	304	7	4
10,000–19,999..	14,283	40	47	23	1.0	1,242	12	9
20,000–39,999..	28,552	25	44	20	0.7	2,748	16	10
40,000 and over.	196,286	22	51	102	0.5	6,952	6	4

The size of the farm was found to have no relationship with the age of the operator. The farm population, however, showed to be in direct relationship with size. This indicates the same fact pointed out in a previous section of this report. It was found also that, although no straight relationship was observed, there was a tendency which indicates that the larger farms are located closer to paved roads than the smaller ones.

The farms with larger capital had, on the average, larger mortgage

indebtednesses, as expressed in absolute figures. However, when expressed in terms of total cuerdas in the farm and as a per cent of the total capital invested, a direct relationship was found to exist up to the group of farms below $40,000 in total capital investments. The largest group of farms showed a significant decline which is a clear indication of their more solid economic solvency.

Total Cuerdas in Farm

The second measure of size of the farms studied which was related to farm earnings and other factors, was total cuerdas in farm. The relationships found are presented in tables 37 to 44.

Other Size Factors. In table 37 the relationships of total cuerdas in farm to other size factors are shown.

TABLE 37. RELATION OF TOTAL CUERDAS IN FARM TO OTHER SIZE FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Total cuerdas in farm: Range	Total cuerdas in farm: Average	Number of farms	Total capital invested	Net cuerdas harvested	Cuerdas in cane harvested	Tons of cane harvested	Cuerdas in tobacco, cotton and corn	Man equivalent	Investment in machinery and equipment
			$						$
Less than 10	7	34	1,606	5	3.1	56	1.4	1.4	43
10– 19	14	48	2,502	10	6.5	117	4.0	1.9	76
20– 39	27	41	4,449	16	9.5	164	5.8	2.5	157
40– 59	49	27	7,952	27	15.7	267	11.0	3.8	251
60– 99	75	26	12,888	44	27.0	576	18.0	5.5	371
100–199	136	31	21,858	73	42.8	729	28.6	7.6	911
200 and over	822	33	138,709	244	172.3	4,556	60.0	34.3	15,764

The same relationships found in the case of total capital invested were observed in this case too. As the size of the farms studied increased, measured by the total cuerdas in farm, the total capital invested, the net cuerdas harvested, the acreage in sugar cane and the tons of cane harvested, the acreage in tobacco, cotton and corn, the number of men employed on the farm as well as the investment in machinery and equipment increased consistently. No inconsistencies or variations could be observed.

Intensity of Land Use and Other Factors. The relationship found between total cuerdas in farm and economic land class was not as clear as that observed when the size of the farm was measured in terms of capital invested. The variations of economic land class with increases in size, as measured by total cuerdas in farm, are not considered to be very significant. However, in both cases, the largest farmers showed the lowest economic land class, which means that they own the better lands (table 38).

The per cent of arable land showed variations with size which, as in the case of capital invested, were considered to be insignificant. In the same way, the proportion of the land used for sugar cane increased with increases in size, as well as the investment in machinery and equipment per net cuerda cultivated. The per cent of the total cuerdas cultivated which was planted to tobacco, cotton and corn showed no downward trend with size increases, as was in the case of capital invested. Both the lowest and the largest groups of farms had a lowest percentages of the land devoted to these secondary crops. The farms in the middle sized groups showed very small variations.

Livestock. No inconsistencies were observed between the relationships of size to livestock when size was measured by either total capital invested

TABLE 38. RELATION OF TOTAL CUERDAS IN FARM TO INTENSITY OF LAND USE AND OTHER FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Total cuerdas in farm: Range	Total cuerdas in farm: Average	Number of farms	Economic land class	Per cent land arable	Per cent of arable land harvested	Per cent net harvested land in cane	Per cent total harvested land in tobacco, cotton and corn	Equipment investment per cuerda harvested
								$
Less than 10	7	34	3.4	90	79	65	22	9
10– 19	14	48	3.8	93	74	67	31	8
20– 39	27	41	3.8	89	65	61	31	10
40– 59	49	27	3.6	93	60	58	32	9
60– 99	75	26	3.5	92	64	61	31	8
100–199	136	31	3.8	93	58	59	33	12
200 and over	822	33	3.3	87	34	71	22	65

or total cuerdas in farm. In table 39 the relationships of total cuerdas in farm to livestock are presented.

A direct close association was found between total cuerdas in farm and total animal units, per cent grazing livestock units, and per cent dairy cow units is of productive animal units. The per cent that the productive livestock of the farm constituted of the total animal units remained rather constant. A tendency, though not a direct relationship, was observed for the larger farms to have a smaller percentage of its capital invested in livestock.

Use of Pasture Lands. In table 40 it is attempted to show the relationships that existed between total cuerdas in farm and use of pasture land.

As in the case of total capital invested, total cuerdas in farm was in direct relation to total cuerdas in available pasture, to the cuerdas in available pasture per grazing livestock unit, to the proportion of the farm

in pasture and to the per cent that the cuerdas in available pasture constituted of the total arable land. Similarly, it was also found that the total number of cuerdas in clear permanent pasture increased with size, and that the proportion it constituted of the total available pasture, conversely, tended to decrease as size of farms decreased. No inconsistent

TABLE 39. RELATION OF TOTAL CUERDAS IN FARM TO LIVESTOCK

240 farms, Southwestern Puerto Rico, 1942–43

Total cuerdas in farm: Range	Total cuerdas in farm: Average	Number of farms	Total animal units	Per cent grazing units	Per cent productive units	Per cent cow units is of productive units	Per cent investment in livestock
Less than 10	7	34	3.5	86	69	50	15
10– 19	14	48	3.8	87	74	54	12
20– 39	27	41	6.2	93	60	59	10
40– 59	49	27	10.5	93	59	56	11
60– 99	75	26	12.5	95	60	59	7
100–199	139	31	24.5	97	60	60	9
200 and over	822	33	145.2	99	64	63	8

TABLE 40. RELATION OF TOTAL CUERDAS IN FARM TO USE OF PASTURE LAND

240 farms, Southwestern Puerto Rico, 1942–43

Total cuerdas in farm		Number of farms	Cuerdas in available pasture				Cuerdas in clear permanent pasture	
Range	Average		Total	Per cent grazing livestock unit	Per cent of total cuerdas in farm	Per cent of total arable land	Total	Per cent of available pasture
Less than 10	7	34	2	0.5	22	25	2	100
10– 19	14	48	4	1.1	26	28	4	100
20– 39	27	41	9	1.5	33	38	8	89
40– 59	49	27	17	1.8	35	38	16	94
60– 99	75	26	29	2.4	38	41	21	72
100–199	136	31	54	2.3	40	43	44	81
200 and over	822	33	478	3.3	58	67	404	85

relations to use of pasture land were found when either one of the two measures of size were used.

Rates of Production and Labor Efficiency. Total cuerdas in farm was in direct association with rates of production and labor efficiency (table 41).

As a measure of size, total cuerdas in farm showed the same relation to rates of production as total capital invested. Crop index (excluding sugar cane) tended to be larger for the smaller farms. The tons of sugar cane produced per cuerda showed increases with increases in size. The only

difference found in the relationships studied which contrasted with that observed in capital invested was the quarts of milk produced per cow-unit. Capital invested showed to be directly associated while total cuerdas in farm showed no apparent relationship.

Labor efficiency was found also to increase with increases in the total cuerdas in farm. This was true within certain limits of size beyond which it started to decline. The highest efficiency, as measured by net cuerdas harvested and cuerdas in sugar cane harvested per man, was found to exist in the group of farms ranging from 100 to 199 cuerdas in size. The tons of sugar cane produced per man did not show a consistent direct relationship; however, there was a marked tendency to increase as the total cuerdas in farm increased. The capital invested per man showed the same direct close association with size. The farms that had the largest

TABLE 41. RELATION OF TOTAL CUERDAS IN FARM TO RATES OF PRODUCTION AND LABOR EFFICIENCY

240 farms, Southwestern Puerto Rico, 1942–43

Total cuerdas in farm: Range	Total cuerdas in farm: Average	Number of farms	Crop index (excluding cane)	Tons of cane per cuerda	Quarts of milk per cow unit	Net cuerdas harvested per man	Cuerdas in cane harvested per man	Tons of cane per man	Capital invested per man	Return on labor per man	Gross income per man
									$	$	$
Less than 10	7	34	139	18	809	3.5	2.2	41	1,157	480	540
10– 19	14	48	89	18	1,017	5.1	3.4	61	1,305	538	706
20– 39	27	41	96	17	774	6.3	3.8	66	1,801	658	811
40– 59	49	27	122	17	780	7.2	4.2	71	2,119	653	834
60– 99	75	26	96	21	754	8.1	4.9	105	2,347	822	1,127
100–199	136	31	108	17	629	9.6	5.6	96	2,880	758	1,067
200 and over	822	33	100	26	809	7.1	5.0	133	4,046	765	1,204

return on labor were those having between 60 to 99 total cuerdas in size. The highest gross income per man was reported by the largest farms.

Farm Expenses. A direct relationship between total cuerdas in farm and farm expenses was observed in the farms studied (table 42).

The total farm expenses increased with increases in size, as measured by the total cuerdas in farm. This same relationship was found in the case of capital invested. Tendencies were also observed for the farm expenses per total cuerda harvested and per net cuerda harvested to increase as the total cuerdas in farm increased. Similarly, the total expenses in hired labor were larger for the larger farms, and it constituted a larger percentage of the total farm cash expenses.

Farm Receipts. The total farm gross income was found to increase consistently with increases in the total cuerdas in farm (table 43). This relationship was identical with the one observed with capital invested.

In the same way, the size of farm, as measured by total acreage, was in direct association with the per cent income from crop sales, the per cent income from sugar cane and with the per cent that the crop sales is of the total value of crops harvested. In the case of the per cent income from tobacco, cotton and corn, the relationships found varied somewhat. The smaller as well as the larger farms reported the smaller percentages.

TABLE 42. RELATION OF TOTAL CUERDAS IN FARM TO FARM EXPENSES

240 farms, Southwestern Puerto Rico, 1942–43

Total cuerdas in farm: Range	Total cuerdas in farm: Average	Number of farms	Farm cash expenses: Total	Farm cash expenses: Per total cuerda harvested	Farm cash expenses: Per net cuerda harvested	Expenses in hired labor: Total	Expenses in hired labor: Per cent of total cash expenses
			$	$	$	$	
Less than 10	7	34	274	42	57	108	39
10– 19	14	48	674	52	69	319	47
20– 39	27	41	848	45	55	485	57
40– 59	49	27	1,540	45	57	961	62
60– 99	75	26	3,107	54	70	1,910	61
100–199	136	31	4,059	46	56	2,609	64
200 and over	822	33	23,178	86	95	17,109	74

TABLE 43. RELATION OF TOTAL CUERDAS IN FARM TO FARM RECEIPTS

240 farms, Southwestern Puerto Rico, 1942–43

Total cuerdas in farm: Range	Total cuerdas in farm: Average	Number of farms	Total farm gross income	Per cent income from crop sales	Per cent crop sales is of total crops value	Per cent income from cane	Per cent income from tobacco, cotton and corn	Per cent income from livestock and products
			$					
Less than 10	7	34	750	50	88	62	6	13
10– 19	14	48	1,352	57	93	72	6	13
20– 39	27	41	2,003	64	94	68	17	6
40– 59	49	27	3,129	66	96	68	17	6
60– 99	75	26	6,187	64	97	76	9	5
100–199	136	31	8,101	66	98	71	13	7
200 and over	822	33	41,293	66	99	77	5	12

The middle sized ones reported the larger. The reverse happened in regard to the per cent income from livestock and livestock products. The extreme sized farms had the highest percentages of their income from this source, while the middle sized farms reported the lower percentages.

Farm Earnings. Farm earnings, as in the case of capital invested, showed to be larger for the larger sized farms, as measured by total acreage in farm (table 44).

The return on capital was directly related to total cuerdas in farm. The per cent return on capital increased up to the group of farms ranging between 60 to 99 cuerdas. Above this acreage in size, the per cent return on capital declined consistently. The capital turnover showed a tendency to increase as the total cuerdas in farm increased; however, the relationship found was not as consistent as the one observed when size was measured by total capital invested. Return on labor, labor income and labor earnings were closely associated with size as measured by total farm acreage. They increased consistently as the size increased. This corroborates once more the great influence that size of farm business had on the financial success of the farms studied in the Lajas Valley Area in the year 1942–43.

TABLE 44. RELATION OF TOTAL CUERDAS IN FARM TO FARM EARNINGS

240 farms, Southwestern Puerto Rico, 1942–43

Total cuerdas in farm		Number of farms	Return on capital	Per cent return on capital	Capital turnover	Return on labor	Labor income	Labor earnings
Range	Average							
			$			$	$	$
Less than 10.	7	34	147	9.1	2.14	667	256	490
10– 19.....	14	48	302	12.1	1.85	1,031	415	666
20– 39.....	27	41	678	15.2	2.22	1,625	730	1,046
40– 59....	49	27	969	12.2	2.54	2,450	866	1,356
60– 99.....	75	26	2,479	19.2	2.08	4.513	2,085	2,520
100–199.....	136	31	3,174	14.5	2.70	5,757	2,452	3,043
200 and over.	822	33	15,266	11.0	3.36	26,225	8,089	9,107

Cuerdas in Sugar Cane Harvested

Cuerdas in sugar cane harvested is another measure of size which was related to farm earnings and other factors in addition to the two previously discussed; namely, total capital invested and total cuerdas in farm. The results of the relationships studied are presented in tables 45 to 55 which follow. As previously shown in this report, only 186 farms of the 240 studied in the Lajas Valley had sugar cane planted in 1942–43. The relationships were established with cuerdas in sugar cane harvested; therefore, the information regarding the 54 farms which did not plant sugar cane was not included. These 54 farms, on the average, were found to be larger in size than the first two groups of farms reporting fewer cuerdas in sugar cane harvested.

Other Size Factors. Table 45 shows the relationship of cuerdas in sugar cane harvested to other size factors. Because of the fact that sugar cane is the major enterprise in the farms of the area, it is considered to be a good

measure of size of business. As in the case of the two previous size factors studied, cuerdas in sugar cane harvested is directly associated with all other size measures selected. Total capital invested, total cuerdas in farm, net cuerdas harvested, tons of sugar cane harvested, cuerdas in tobacco, cotton and corn, man equivalent, and investment in machinery and equipment, all increased as the cuerdas in sugar cane increased.

TABLE 45. RELATION OF CUERDAS IN SUGAR CANE HARVESTED TO OTHER SIZE FACTORS

186 farms, Southwestern Puerto Rico, 1942–43

Cuerdas in sugar cane harvested: Range	Cuerdas in sugar cane harvested: Average	Number of farms	Total capital invested	Total cuerdas in farm	Net cuerdas harvested	Tons of cane harvested	Cuerdas in tobacco, cotton and corn	Man equivalent	Investment in machinery and equipment
			$						$
Less than 5.0	3.0	35	3,289	26	10	47	7.3	2.0	64
5.0– 9.9	7.6	47	4,372	26	12	134	3.5	2.3	128
10.0–19.9	13.5	36	7,658	44	27	215	13.7	3.5	229
20.0–49.9	31.7	31	13,226	126	50	573	10.5	5.4	515
50.0–99.9	64.1	21	26,871	143	89	1,203	19.9	9.2	1,063
100 and over	354.3	16	245,706	1,271	416	9,417	40.1	61.9	31,729

TABLE 46. RELATION OF CUERDAS IN SUGAR CANE HARVESTED TO INTENSITY OF LAND USE AND OTHER FACTORS

186 farms, Southwestern Puerto Rico, 1942–43

Cuerdas in sugar cane harvested: Range	Cuerdas in sugar cane harvested: Average	Number of farms	Economic land class	Per cent land arable	Per cent of arable land harvested	Per cent net harvested land in cane	Per cent total harvested land in tobacco, cotton and corn	Equipment investment per cuerda harvested
								$
Less than 5.0	3.0	35	4.0	86	46	29	55	6
5.0– 9.9	7.6	47	3.5	86	51	65	24	11
10.0–19.9	13.5	36	3.2	93	67	50	44	8
20.0–49.9	31.7	31	3.1	74	54	63	18	10
50.0–99.9	64.1	21	2.6	93	66	72	20	12
100.0 and over	354.3	16	1.9	90	36	85	9	76

Intensity of Land Use and Other Factors. In table 46, cuerdas in sugar cane harvested was also related to intensity of land use and other factors.

It is definitely shown here, once more, that the best lands were in the hands of the larger farmers, as shown by the consistent decline of the economic land class with increases in size, as measured by cuerdas in sugar cane harvested. The per cent of arable land showed no relationship with size, and it varied very little as to the average per cent which

it constituted of the total farm acreage. The per cent of the arable land which was cultivated, contrary to the tendencies of decreasing with size increases which was observed before, did not show any significant relationship with cuerdas in sugar cane harvested. However, the largest farms had always the smallest percentage. The proportion of the net cuerdas harvested which was in sugar cane, showed again the tendency of increasing with size increases. The proportion of the total cuerdas harvested which was in tobacco, cotton and corn, as observed before, tended to decrease as the size of the farm increased. The investment in machinery and equipment per net cuerda harvested, tended to increase with increases in size.

Livestock. As the size of the farms studied increased, the total animal units on the farm showed consistent increases too (table 47).

TABLE 47. RELATION OF CUERDAS IN SUGAR CANE HARVESTED TO LIVESTOCK

186 farms, Southwestern Puerto Rico, 1942–43

Cuerdas in sugar cane harvested		Number of farms	Total animal units	Per cent grazing units	Per cent productive units	Per cent cow units is of productive units	Per cent investment in livestock	Average value per productive unit
Range	Average							
								$
Less than 5.0......	3.0	35	6.3	92	70	54	14	70
5.0– 9.9.........	7.6	47	6.6	92	72	60	10	60
10.0–19.9.........	13.5	36	10.0	96	62	66	11	84
20.0–49.9.........	31.7	31	19.6	97	67	60	11	62
50.0–99.9.........	64.1	21	21.9	97	52	57	6	72
100.0 and over.....	354.3	16	220.1	99	60	64	7	68

The grazing livestock of the farms showed also to be consistent in its relationship with size. It increased as the cuerdas in sugar cane harvested increased. The population of the livestock which was productive showed again no significant variation with size and furthermore, the relative amounts did not vary too much either. Cuerdas in sugar cane harvested and the relative amounts of cow-units on the farm showed but a slight tendency, if any, to be related with each other. Perhaps there exists a very slight tendency to increase with size increases, but it cannot be considered significant. In the case of the relative importance of the investments in livestock measured in terms of the total investment, it showed a marked tendency to decrease as size increased. The quality of the productive livestock, as measured by its average value per unit, was found to show no significant relationship with cuerdas in sugar cane harvested.

Use of Pasture Land. Table 48 is presented to show the relation of cuerdas in sugar cane harvested to use of pasture land.

The total number of cuerdas in available and clear permanent pasture increased with size increases, as measured by cuerdas in sugar cane harvested. The cuerdas in available pasture per grazing livestock unit did not show any significant relationship with this measure of size, as was the case with the capital invested and total farm acreage. The same happened with the per cent that the available pasture constituted of both the total cuerdas in farm and of the total arable land. The extreme sized farms, though, showed the highest percentages. In this respect, cuerdas in sugar cane harvested differed from the other measures of size. The per cent that the clear permanent pasture was of the total available pastures showed again the tendency to decline with increases in size.

TABLE 48. RELATION OF CUERDAS IN SUGAR CANE HARVESTED TO USE OF PASTURE LAND

186 farms, Southwestern Puerto Rico, 1942–43

Cuerdas in sugar cane harvested			Cuerdas in available pasture				Cuerdas in clear permanent pasture	
Range	Average	Number of farms	Total	Per grazing in livestock unit	Per cent of total cuerdas in farm	Per cent of total arable land	Total	Per cent of available pasture
Less than 5.0	3.0	35	14	2.4	53	62	11	79
5.0– 9.9	7.6	47	10	1.7	38	44	10	100
10.0–19.9	13.5	36	13	1.4	30	32	12	92
20.0–49.9	31.7	31	42	2.2	34	45	39	93
50.0–99.9	64.1	21	46	2.2	32	34	42	91
100 and over	354.3	16	741	2.2	58	65	631	85

Irrigation. Irrigation practices were carried on mostly in the larger farms studied. In table 49, where size of farm is measured by cuerdas in sugar cane harvested, it is observed that the only group of farms which practiced no irrigation at all was the smallest one, that is, those reporting less than 5.0 cuerdas in cane. All the other groups practiced irrigation, but to different extents. The first group of farms which reported irrigation equipment was that ranging between 20 to 50 cuerdas in sugar cane harvested.

A very clear direct relationship was observed which indicated that the larger the farms the larger the amount invested in irrigation equipment, and the larger the acreage irrigated. Irrigation equipment, as pointed out previously, is very expensive and only rich farmers could afford to have it. The smaller farms that reported irrigating part of their canes did it with either borrowed or hired outside facilities.

Rates of Production. Rates of production have never shown to be in

close association with size. However, in the farms studied, a direct relationship was generally observed. Of course, the higher rates of production observed were very probably due to other factors such as better lands, better farm practices, better pastures and better livestock, which were found to be intimately associated with size. In table 50 it is shown how

TABLE 49. RELATION OF CUERDAS IN SUGAR CANE HARVESTED TO IRRIGATION

186 farms, Southwestern Puerto Rico, 1942–43

Cuerdas in sugar cane harvested		Number of farms	Investment in irrigation equipment				Cuerdas of sugar cane irrigated		
Range	Average		Total	Per cuerda of cane harvested	Per cuerda of cane irrigated	Per cent of total capital	Total	Per cent of total arable land	Per cent of cane harvested
			$	$	$				
Less than 5.0	3.0	35	0	0	0	0.0	0.0	0.0	0.0
5.0– 9.9	7.6	47	0	0	0	0.0	0.2*	0.9	2.8
10.0–19.9	13.5	36	0	0	0	0.0	0.4*	1.0	3.1
20.0–49.9	31.7	31	15	1	15	0.1	1.0	1.1	3.2
50.0–99.9	64.1	21	252	4	56	0.9	4.5	3.4	7.0
100.0 and over	354.3	16	18,815	53	96	7.7	196.3	17.1	55.4

* Irrigated with outside equipment.

TABLE 50. RELATION OF CUERDAS IN SUGAR CANE HARVESTED TO RATES OF PRODUCTION

186 farms, Southwestern Puerto Rico, 1942–43

Cuerdas in sugar cane harvested		Number of farms	Crop index (excluding cane)	Tons of cane per cuerda	Tons of sugar per cuerda	Per cent sucrose content of cane	Quarts of milk per cow unit
Range	Average						
Less than 5.0	3.0	35	134	16	1.9	12.56	908
5.0– 9.9	7.6	47	104	18	2.3	13.08	764
10.0–19.9	13.5	36	104	16	2.1	13.00	712
20.0–49.9	31.7	31	108	18	2.3	12.94	573
50.0–99.9	64.1	21	115	19	2.4	12.98	595
100.0 and over	354.3	16	80	27	3.4	12.68	815

size, as measured by cuerdas in sugar cane harvested kept a close association with rates of production.

Crop index (excluding sugar cane) indicated the same tendency to decline in the larger farms. On the other hand, both tons of sugar cane per cuerda and tons of sugar produced per cuerda increased as the size of the farms increased. Conversely, the sucrose content of the sugar cane harvested in the smaller farms showed to be higher than for the larger

farms. This is very probably explained by the fact that the smaller farms grew the sugar cane under drier conditions. On the smaller farms, sugar cane is generally planted in steeper land, and, furthermore, these farms very seldom practice irrigation. Of course, this finding is something that deserves special and further study.

It was also expected here to find the production of milk per cow unit to increase with size increases. However, the reverse tendency was observed. The largest sized farms were the only ones which showed an increase in milk production per cow above the preceding group, thus breaking the relationship. Apparently, there is an inconsistency here which may be explained by the fact that the farms with the larger sugar cane acreages did not report having either the higher quality livestock nor the higher carrying capacity pastures.

TABLE 51. RELATION OF CUERDAS OF SUGAR CANE HARVESTED TO LABOR EFFICIENCY

186 farms, Southwestern Puerto Rico, 1942-43

Cuerdas in sugar cane harvested: Range	Cuerdas in sugar cane harvested: Average	Number of farms	Net cuerdas harvested per man	Cuerdas in cane harvested per man	Tons of cane per man	Capital invested per man	Return on labor per man	Gross income per man
						$	$	$
Less than 5.0	3.0	35	5.2	1.5	24	1,678	512	592
5.0- 9.9	7.6	47	5.0	3.2	57	1,866	521	688
10.0-19.9	13.5	36	7.7	3.8	61	2,174	687	887
20.0-49.9	31.7	31	9.2	5.9	106	2,440	779	1,103
50.0-99.9	64.1	21	9.6	7.0	131	2,919	924	1,261
100.0 and over	354.3	16	6.7	5.7	152	3,967	792	1,243

Labor Efficiency. The efficiency in the use of labor has been found, so far, to be directly related with size, up to certain limits, beyond which it has been found to decrease. It is attempted in table 51 to present the relationship of labor efficiency with cuerdas in sugar cane harvested during the year of study, 1942-43.

Both the tons of sugar cane per man and the capital invested per man increased consistently with increases in the sugar cane acreage. However, in the case of the net cuerdas harvested per man, the cuerdas in sugar cane harvested per man, the return on labor per man and the gross income per man, consistent increases were found up to the group of farms reporting sugar cane acreages ranging between 50 to 100 cuerdas. This group had the highest efficiency in the use of labor. The next and largest group in size showed to use labor less efficiently. The same finding is once more corroborated.

Farm Expenses. Total farm cash expenses were, logically, larger for the larger farms (table 52). The same relationship was observed between the total farm cash expenses per total cuerda harvested and size, as measured by cuerdas in sugar cane harvested. Size was also found to be directly related to the proportion that the total hired expenses represented of the total farm expenses. Increases were not consistent but the tendency was clearly marked.

As to the hired labor expenses in sugar cane, both per cuerda and per ton of cane harvested, a direct relationship was found showing general increases with increases in size. This indicates definitely that the larger farms applied more units of production per cuerda in cane than the smaller ones. The per cent that the hired labor expenses in sugar cane constituted

TABLE 52. RELATION OF CUERDAS IN SUGAR CANE HARVESTED TO FARM EXPENSES

186 farms, Southwestern Puerto Rico, 1942–43

Cuerdas in sugar cane harvested		Number of farms	Farm cash expenses			Hired labor expense in sugar cane			Fertilizer cost per cuerda of cane
Range	Average		Total	Per total cuerda harvested	Per cent hired labor	Per cuerda of cane	Per ton of cane	Per cent of total hired labor	
			$	$		$	$	$	
Less than 5.0.....	3.0	35	409	31	49	21	1.38	32	7
5.0– 9.9........	7.6	47	775	54	52	37	2.08	70	7
10.0–19.9........	13.5	36	1,394	45	65	38	2.40	57	7
20.0–49.9........	31.7	31	3,106	54	59	42	2.34	73	8
50.0–99.9........	64.1	21	5,922	59	67	49	2.59	78	5
100.0 and over....	354.3	16	44,206	102	74	67	2.52	72	9

of the total hired labor expenses showed a clear tendency to increase as the cuerdas in sugar cane harvested increased. Although a slight tendency for the total fertilizer expenses per cuerda of cane harvested to increase with size was observed, the variation can be described as rather insignificant.

Farm Receipts. Total farm gross income increased with increases in cuerdas in sugar cane harvested (table 53). It is very natural to expect this increase in farm receipts with increases in size. What is really significant is that both the per cent income from crops sales and the per cent that crop sales is of the total value of crops harvested increased with increases in size. The per cent that the total receipts from sugar constituted of the farm gross income showed again the same tendency to increase with size. The per cent income from tobacco, cotton and corn indicated the same tendency observed before to decrease with increases in size, measured this time by cuerdas in sugar cane harvested.

Livestock and livestock products constituted a less important source of income for the larger farms. However, the relationship was broken by the largest farms, which showed a marked increase to a higher level but never as high as that of the first two groups of smaller farms.

Farm Earnings. Size and farm earnings proved once more to be intimately related in Southwestern Puerto Rico. Return on labor, labor income, and labor earnings showed consistent increases with increases in size, as measured by cuerdas in sugar cane harvested (table 54).

TABLE 53. RELATION OF CUERDAS IN SUGAR CANE HARVESTED TO FARM RECEIPTS

186 farms, Southwestern Puerto Rico, 1942–43

Cuerdas in sugar cane harvested: Range	Cuerdas in sugar cane harvested: Average	Number of farms	Total farm gross income	Per cent income from crop sales	Per cent crop sales is of total crops value	Per cent income from cane	Per cent income from tobacco, cotton and corn	Per cent income from livestock and products
			$					
Less than 5.0	3.0	35	1,160	52	89	33	27	16
5.0– 9.9	7.6	47	1,612	55	93	68	6	12
10.0–19.9	13.5	36	3,124	64	96	55	24	10
20.0–49.9	31.7	31	5,976	62	97	78	7	6
50.0–99.9	64.1	21	11,610	68	98	83	7	3
100.0 and over	354.3	16	76,998	68	99	86	1	10

TABLE 54. RELATION OF CUERDAS IN SUGAR CANE HARVESTED TO FARM EARNINGS

186 farms, Southwestern Puerto Rico, 1942–43

Cuerdas in sugar cane harvested: Range	Cuerdas in sugar cane harvested: Average	Number of farms	Return on capital	Per cent return on capital	Capital turnover	Return on labor	Net farm cash income	Labor income	Labor earnings
			$			$	$	$	$
Less than 5.0	3.0	35	306	9.3	2.84	1,004	606	379	706
5.0– 9.9	7.6	47	389	8.9	2.71	1,220	667	405	723
10.0–19.9	13.5	36	1,184	15.5	2.45	2,421	1,483	1,112	1,460
20.0–49.9	31.7	31	2,194	16.6	2.21	4,223	2,657	1,793	2,312
50.0–99.9	64.1	21	5,018	18.7	2.31	8,502	5,388	3,975	4,502
100.0 and over	354.3	16	27,932	11.4	3.19	49,050	30,676	14,906	16,168

The return on capital showed a close direct association with size. The per cent return on capital, however, had again a top limit in the group of farms which ranged from 50 to 100 cuerdas in sugar cane. This group of farms showed, on the average, around 19 per cent return on capital. The next and largest group showed a substantial decline to 11 per cent. Contrary to the previous relationships observed, the capital turnover was larger for the smaller farms with a definite tendency to decrease with

size increases. An exception is noticed in the largest farms which jumped up from 2.31 to 3.19 years. This apparent inconsistency was only present in this case, that is, when cuerdas in sugar cane was used as a measure of size. It may be concluded that the larger the acreage in sugar cane the less number of years needed for the gross receipts to equalize the capital investment. This was true within certain limits, in our case, up to 100 cuerdas in sugar cane.

Farm Mortgage Indebtedness. Cuerdas in sugar cane harvested, as a measure of size, was also related to farm mortgage indebtedness, and the results found are presented in table 55.

TABLE 55. RELATION OF CUERDAS IN SUGAR CANE HARVESTED TO FARM MORTGAGE INDEBTEDNESS AND OTHER FACTORS

186 farms, Southwestern Puerto Rico, 1942–43

Cuerdas in sugar cane harvested					Distance to nearest paved road	Farm mortgage indebtedness		
Range	Average	Number of farms	Age of operator	Farm population	(kms.)	Total	Per total cuerdas in farm	Per cent of total capital
						$	$	
Less than 5.0	3.0	35	51	13	1.4	293	11	9
5.0– 9.9	7.6	47	50	13	0.9	215	8	5
10.0–19.9	13.5	36	45	12	1.1	222	5	3
20.0–49.9	31.7	31	46	36	0.8	1,127	9	9
50.0–99.9	64.1	21	47	26	0.2	2,396	17	9
100.0 and over	354.3	16	52	95	0.5	8,161	6	3

The age of the operator and size of farm showed again no relationship to each other. The same as before, larger farms were found to support a larger farm population, on the average. In general they were also located at shorter distances from paved roads, as is indicated in table 55. This factor is of special significance since the hauling and marketing of farm products is facilitated, and consequently its cost is reduced.

The mortgage indebtedness of the farms increased as size increased, but no relationship was observed when the mortgage burden of the farms was expressed per cuerda in farm or as a per cent of the total capital invested. The only point of interest shown again is that the largest sized farms had the least mortgage burden per cuerda, and, together with the group of farms ranging between 10 to 20 cuerdas in cane, also showed to have the least percentage of its capital mortgaged. It should be kept in mind that the economic solidity of the larger farmers, in general, is unquestionable.

Tons of Sugar Cane Harvested

Tons of sugar cane harvested, as well as the cuerdas in sugar cane was also related to farm earnings, and other factors. This factor, used here as a measure of size, is also influenced by rates of production, which have been found to be closely related to size. For this reason it is considered to be a good measure of size of business in the area studied. As in the case of cuerdas in sugar cane harvested, the information regarding the 54 farms which did not grow sugar cane in 1942–43 was not included in tables 56 to 60 presented below. These farms were found to be larger in size than the first three groups of farms with fewer tons of sugar cane produced.

Other Size Factors. In table 56 the relation of tons of sugar cane harvested to other size factors is presented.

TABLE 56. RELATION OF TONS OF SUGAR CANE HARVESTED TO OTHER SIZE FACTORS

186 farms, Southwestern Puerto Rico, 1942–43

Tons of sugar cane harvested		Number of farms	Total capital invested	Total cuerdas in farm	Net cuerdas harvested	Cuerdas in cane harvested	Tons of sugar produced	Man equivalent	Investment, in machinery and equipment
Range	Average								
			$						$
Less than 75	46	39	3,221	26	11	3.7	5.7	2.0	70
75–149	118	36	3,919	25	14	8.3	15.4	2.3	104
150–299	198	39	6,887	41	21	12.8	25.4	3.1	202
300–599	425	24	12,796	77	44	24.2	55.3	4.7	415
600–1199	850	21	22,695	199	83	49.5	110.3	7.7	1,264
1200 and over	6,207	27	154,922	793	274	236.5	789.3	40.8	18,949

Tons of sugar cane harvested showed a direct close association with other size factors. Total capital invested, total cuerdas in farm, net cuerdas harvested, cuerdas in sugar cane harvested, tons of sugar produced and man equivalent, all were found to increase consistently with increases in size.

Intensity of Land Use. Economic land class was found to be inversely related to tons of sugar cane harvested as shown in table 57. The better lands in the hands of the larger sized farmers accounts for a great part of the higher tonnage of sugar cane produced.

The larger farms had approximately the same per cent of land arable, but they had cultivated a lower per cent of it as compared to the smaller farms. A very clear tendency for the larger farms to have higher percentage of the net cuerdas in crop in sugar cane was very definitely ob-

served again. Larger farms had also larger investments in machinery and equipment per net cuerda harvested. They were also found to irrigate, by far, a larger proportion of the land in cane. The proportion of total animal units which was work-stock was also found to be somewhat larger for the larger farms, as measured in this occasion by tons of sugar cane harvested.

TABLE 57. RELATION OF TONS OF SUGAR CANE HARVESTED TO INTENSITY OF LAND USE AND OTHER FACTORS

186 farms, Southwestern Puerto Rico, 1942–43

Tons of sugar cane harvested: Range	Tons of sugar cane harvested: Average	Number of farms	Economic land class	Per cent land arable	Per cent of arable land harvested	Per cent net harvested land in cane	Equipment investment per cuerda harvested	Per cent cuerdas in cane irrigated	Per cent work-stock is of total animal units
							$		
Less than 75....	46	39	4.1	87	47	35	7	0.0	32
75– 149.......	118	36	3.3	91	61	60	8	0.0	36
150– 299......	198	39	3.3	90	57	60	10	3.8	31
300– 599.......	425	24	3.2	91	63	55	9	6.4	38
600–1199.......	850	21	3.0	77	55	59	15	2.4	37
1200 and over...	6,207	27	2.0	90	38	86	69	50.3	40

TABLE 58. RELATION OF TONS OF SUGAR CANE HARVESTED TO RATES OF PRODUCTION AND LABOR EFFICIENCY

186 farms, Southwestern Puerto Rico, 1942–43

Tons of sugar cane harvested: Range	Tons of sugar cane harvested: Average	Number of farms	Tons of cane per cuerda	Tons of sugar per cuerda	Per cent sucrose content of cane	Tons of cane per man	Net cuerdas harvested per man	Cuerdas in cane harvested per man	Capital invested per man	Gross income per man
									$	$
Less than 75...	46	39	12	1.5	12.48	23	5.3	1.9	1,614	551
75– 149......	118	36	14	1.9	12.97	52	6.0	3.6	1,719	689
150– 299......	198	39	15	2.0	12.85	63	6.7	4.1	2,198	774
300– 599......	425	24	18	2.3	13.02	91	9.4	5.2	2,737	1,147
600–1199......	850	21	17	2.2	12.98	110	10.8	6.4	2,946	1,177
1200 and over..	6,207	27	26	3.3	12.72	152	6.7	5.8	3,797	1,250

Rates of Production and Labor Efficiency. The larger farms showed to have better rates of production than the smaller ones (table 58). For instance, the tons of sugar cane as well as of sugar produced per cuerda increased consistently with size increases. The sucrose content of the cane produced, however, showed no relationship with tons of sugar cane harvested. Perhaps there is a slight tendency for the sucrose content to increase with size, but it does not seem to be very significant.

Generally speaking, the labor efficiency of the farms of the area was found to be higher for the larger ones and vice versa. Definite consistent

increases with size were observed in the tons of sugar cane per man, the capital invested per man, and the gross income per man. It is also true that net cuerdas harvested per man and cuerdas in sugar cane harvested per man showed a direct relationship with size. This association however, is conditioned by certain top limits in size, in this case, by the very largest group of farms. The farms having the highest efficiency in the use of labor, as measured by these two factors, were those ranging from 600 to 1200 tons of sugar cane harvested. The next and largest group of farms, showed a substantial decline in labor efficiency. Once more this relationship is corroborated.

Farm Expenses and Receipts. It is the objective of table 59 to show the relationships found between tons of sugar cane harvested and farm expenses and receipts.

TABLE 59. RELATION OF TONS OF SUGAR CANE HARVESTED TO FARM EXPENSES AND RECEIPTS

186 farms, Southwestern Puerto Rico, 1942–43

Tons of sugar cane harvested		Number of farms	Hired labor expenses in sugar cane			Fertilizer costs per cuerda of cane	Total cane receipts per cuerda	Per cent income from cane	Total farm gross income
Range	Average		Per cent of total hired labor	Per cuerda of cane	Per ton of cane				
				$	$	$	$		$
Less than 75	46	39	39	22	1.83	5	100	34	1,098
75– 149	118	36	66	30	2.09	6	117	62	1,572
150– 299	198	39	67	38	2.45	6	124	65	2,427
300– 599	425	24	63	37	2.14	7	143	64	5,363
600–1199	850	21	71	43	2.49	8	139	76	9,068
1200 and over	6,207	27	73	66	2.53	8	186	86	50,987

The larger farms were found to use more hired labor per cuerda of cane harvested. The per cent of the total hired labor expenses which these larger farms used on sugar cane was also found to be larger than for the smaller farms. As is hereby demonstrated, the larger farmers applied more units of production per cuerda of cane harvested. They intensified in the sugar cane enterprise. However, when the hired labor expenses in sugar cane were expressed per ton of sugar cane harvested, no apparent good relationship was observed, except a tendency to increase with increases in sugar cane tonnage.

The higher yields per cuerda of the larger farms were apparently enough to compensate for the larger hired expenses per cuerda of sugar cane in which they incurred. These higher yields are partly accounted for by the heavier amounts of fertilizer per cuerda which these larger farms applied, as shown in table 59. As the tons of sugar cane harvested increased, the total fertilizer expenses per cuerda of cane harvested increased also.

The total farm gross income, obviously, increased as size increased. The per cent of the gross income which was constituted by the total receipts from sugar cane, was in direct relationship with size. They both increased together. The same relationship was observed between total receipts from sugar cane per cuerda of cane harvested and size. In spite of higher labor expenses, the gross output per cuerda of cane was definitely higher for the larger farms.

Farm Earnings. It is attempted in table 60 to indicate the relationships found between tons of sugar cane harvested, as a measure of size, and farm earnings.

Once more the return on capital was found to be greater for the larger farms. However, the per cent return on capital did not show any relationship. It was found that it tended to increase up to the group of farms

TABLE 60. RELATION OF TONS OF SUGAR CANE HARVESTED TO FARM EARNINGS

186 farms, Southwestern Puerto Rico, 1942–43

Tons of sugar cane harvested		Number of farms	Return on capital	Per cent return on capital	Capital turnover	Net farm cash income	Labor income	Labor earnings
Range	Average							
			$			$	$	$
Less than 75...	46	39	252	7.8	2.93	563	337	655
75– 149......	118	36	395	10.1	2.49	746	452	784
150– 299......	198	39	686	10.0	2.84	940	626	964
300– 599......	425	24	2,432	19.0	2.39	2,810	2,102	2,591
600–1199......	850	21	3,473	15.3	2.50	4,013	2,628	3,279
1200 and over..	6,207	27	18,883	12.2	3.04	20,559	10,755	11,621

which had a total production of sugar cane ranging from 300 to 600 tons. Beyond this size, it went down substantially, corroborating once more the previous relationships found. Capital turnover showed no relationship with sugar cane tonnage; however, the farms having the largest cane tonnage had the largest capital turnover. That is, it takes 3.04 years for the gross receipts which they had in 1942–43 to equalize the capital invested.

The net farm cash income as well as the labor income and the labor earnings were found again to be closely and directly associated with size. They showed consistent increases as the tons of sugar cane harvested increased.

Man Equivalent

The number of men employed in a farm during the year is a good measure of its size. In the absence of a better measure of total volume of productive work accomplished by labor, man equivalent may be used as a measure to size of business. For this reason it was also included here for discussion

and its relationships with farm earnings and other factors are presented in tables 61 to 67.

Other Size Factors. As in the case of other size measures studied, there was a direct relationship between man equivalent and other size factors.

TABLE 61. RELATION OF MAN EQUIVALENT TO OTHER SIZE FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Man equivalent: Range	Man equivalent: Average	Number of farms	Total capital invested	Total cuerdas in farm	Net cuerdas harvested	Cuerdas in cane harvested	Tons of cane harvested	Cuerdas in tobacco, cotton and corn	Investment in machinery and equipment
			$						$
Less than 1.5 . . .	1.0	32	1,775	11	5	3.0	46	2.1	38
1.5–1.9	1.7	36	2,894	16	10	6.5	101	3.9	52
2.0–2.9	2.4	53	3,879	26	14	7.4	129	6.3	109
3.0–4.9	3.9	50	9,946	70	30	12.6	220	18.0	337
5.0–9.9	7.0	41	22,963	167	66	32.5	565	34.6	687
10.0 and over . .	41.1	28	155,589	857	286	223.6	5,832	44.7	18,662

TABLE 62. RELATION OF MAN EQUIVALENT TO INTENSITY OF LAND USE AND OTHER FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Man equivalent: Range	Man equivalent: Average	Number of farms	Economic land class	Per cent land arable	Per cent of arable land harvested	Per cent net harvested land in cane	Per cent total harvested land in tobacco, cotton and corn	Equipment investment per cuerda harvested
								$
Less than 1.5	1.0	32	3.6	91	55	56	29	7
1.5–1.9	1.7	36	3.5	92	66	66	30	5
2.0–2.9	2.4	53	3.9	89	60	54	36	8
3.0–4.9	3.9	50	4.3	93	46	43	43	11
5.0–9.9	7.0	41	3.4	89	44	49	41	10
10.0 and over	41.1	28	2.3	88	38	78	15	65

With an increase of man equivalent there was an increase in total capital invested, total cuerdas in farm, net cuerdas harvested, cuerdas in sugar cane harvested, tons of sugar cane harvested, cuerdas in tobacco, cotton and corn, and investment in machinery and equipment.

Intensity of Land Use and Other Factors. Man equivalent did not show a very close relationship with economic land class. A tendency was observed for the larger farms to show a lower economic land class which means that they tend to have the better lands. It was also shown again that the largest farms had definitely the better lands (table 62).

The per cent of arable land did not vary too much for both smaller and larger farms. This same relationship had been observed before. The larger farms indicated a tendency to have a lower per cent of the arable land cultivated; however, a larger percentage of the net area cultivated was planted in sugar cane. The per cent of the total cuerdas harvested represented by tobacco, cotton and corn was found to be smaller, on the average, for the larger farms. Farms with a larger man equivalent were found to have larger investment in machinery and equipment per net cuerda harvested.

Livestock. The larger farms, on the basis of man equivalent, had more total animal units (table 63).

TABLE 63. RELATION OF MAN EQUIVALENT TO LIVESTOCK

240 farms, Southwestern Puerto Rico, 1942–43

Man equivalent		Number of farms	Total animal units	Per cent grazing units	Per cent productive units	Per cent cow units is of productive units	Per cent investment in livestock	Average value per productive units
Range	Average							
								$
Less than 1.5...	1.0	32	3.6	86	71	51	14	65
1.5–1.9........	1.7	36	4.2	89	70	57	10	72
2.0–2.9........	2.4	53	6.4	91	67	57	11	62
3.0–4.9........	3.9	50	15.3	96	65	60	13	81
5.0–9.9........	7.0	41	29.7	97	68	61	11	80
10.0 and over...	41.1	28	147.2	99	61	63	7	68

The proportion of grazing livestock on the farms studied was larger for the larger farms. Very little variation, however, was found in the farms studied as to the per cent of the livestock accounted for by productive animals. The proportion that dairy cows constituted of all the productive livestock in the farms showed also very little variation with man equivalent. Perhaps a slight tendency to increase with size was observed. Livestock investments in general were relatively smaller for the larger farms. Although a slight tendency was observed for the average value per productive animal unit to increase with size, as measured by man equivalent, its significance is rather negligible.

Use of Pasture Land. As in the case of other size factors studied, the total number of cuerdas in available pasture as well as those in clear permanent pasture were found to increase with size, measured on the basis of man equivalent (table 64).

The total number of cuerdas in available pasture per grazing livestock unit were found to increase with increases in size. The larger farms reported also having a larger per cent of the total farm acreage in available

pasture. A tendency was also observed for the larger farms to have a higher proportion of their total arable land in available pasture. The relative importance of the clear permanent pasture, measured in terms of the total available pasture, tended to decrease as size increased.

Irrigation. In table 65 the relation of man equivalent to irrigation is presented.

TABLE 64. RELATION OF MAN EQUIVALENT TO USE OF PASTURE LAND

240 farms, Southwestern Puerto Rico, 1942-43

Man equivalent		Number of farms	Cuerdas in available pasture				Cuerdas in clear permanent pasture	
Range	Average		Total	Per grazing livestock unit	Per cent of total cuerdas in farm	Per cent of total arable land	Total	Per cent of available pasture
Less than 1.5	1.0	32	5	1.5	43	47	4	95
1.5-1.9	1.7	36	5	1.3	31	33	3	68
2.0-2.9	2.4	53	10	1.7	39	44	8	77
3.0-4.9	3.9	50	35	2.4	51	54	28	78
5.0-9.9	7.0	41	84	2.9	51	57	69	82
10.0 and over	41.1	28	470	3.2	55	63	403	81

TABLE 65. RELATION OF MAN EQUIVALENT TO IRRIGATION

240 farms, Southwestern Puerto Rico, 1942-43

Man equivalent		Number of farms	Investment in irrigation equipment				Cuerdas in sugar cane irrigated		
Range	Average		Total	Per cuerda of cane harvested	Per cuerda of cane irrigated	Per cent of total capital	Total	Per cent of total arable land	Per cent of cane harvested
			$	$	$				
Less than 1.5	1.0	32	0	0	0	0.0	0.0	0.0	0.0
1.5-1.9	1.7	36	0	0	0	0.0	0.0	0.0	0.0
2.0-2.9	2.4	53	0	0	0	0.0	0.2*	0.8	2.5
3.0-4.9	3.9	50	10	1	53	0.1	0.2	0.3	1.4
5.0-9.9	7.0	41	61	2	53	0.3	1.1	0.8	3.5
10.0 and over	41.1	28	10,851	48	94	7.0	115.2	15.3	51.5

* Irrigated with outside equipment.

The same as in the previous measures of size of business, the farmers employing larger amounts of labor during the year studied also had larger investments in irrigation equipment and, consequently, irrigated a larger proportion of their lands. The smaller farms had no investments at all and, if some of them reported having practiced some irrigation, it was with the aid of hired or borrowed equipment. Practically all the irrigation in

the area is done by the farmers employing over 10 or more men during the year.

Rates of Production and Labor Efficiency. Man equivalent was also related to rates of production and labor efficiency. The results are presented in table 66.

The same tendency for the larger farms to have a lower crops index (excluding sugar cane) was found. As to the tons of sugar cane per cuerda, they were found again to increase with increases in size. The quarts of milk produced per cow unit did not show any significant relationship with size, as measured by man equivalent.

Labor efficiency, in general, was found to be directly associated with man equivalent, but it also indicated the same tendency of decreasing beyond certain limits of size. The efficiency in the use of labor, when measured by

TABLE 66. RELATION OF MAN EQUIVALENT TO RATES OF PRODUCTION AND LABOR EFFICIENCY

Relation of man equivalent to rates of production and labor efficiency

Man equivalent: Range	Man equivalent: Average	Number of farms	Crop index (excluding cane)	Tons of cane per cuerda	Quarts of milk per cow unit	Net cuerdas harvested per man	Cuerdas in cane harvested per man	Tons of cane per man	Capital invested per man	Return on labor per man	Gross income per man
									$	$	$
Less than 1.5....	1.0	32	120	15	727	5.3	3.0	45	1,759	566	652
1.5–1.9.........	1.7	36	98	16	897	5.7	3.8	59	1,694	563	678
2.0–2.9.........	2.4	53	103	17	779	5.8	3.1	53	1,611	533	655
3.0–4.9.......	3.9	50	113	17	904	7.6	3.2	56	2,552	647	903
5.0–9.9.........	7.0	41	103	17	720	9.5	4.7	81	3,304	786	1,116
10.0 and over....	41.1	28	96	26	792	7.0	5.4	142	3,788	778	1,210

cuerdas in sugar cane harvested per man, tons of sugar per man, capital invested per man, and gross income per man, showed general consistent increases with size increases. However, when measured in terms of net cuerdas harvested per man, it increased consistently up to the group of farms ranging from 5 to 10 men employed. When it was measured in terms of return on labor per man, labor efficiency showed practically consistent increases up to the same group of farms. The farms employing ten or more men during the year had a decline in labor efficiency.

Farm Earnings. Size, measured this time by man equivalent, and labor earnings were found once more to be directly associated (table 67).

The return on capital showed definite increases with increases in size. No straight relationship, however, was found between the per cent return on capital and man equivalent. A tendency to increase up to the farms ranging from 5 to 10 men in man equivalent, was observed. This group

of farms had the highest per cent return on capital of 14.6. The largest group of farms showed a substantial decline. A tendency for the total receipts of the larger farms to take more years to equalize the total capital invested was also found. The larger farms tended to have, therefore, a larger capital turnover, but the differences are rather insignificant.

The return on labor, the labor income and the labor earnings of the farms studied were intimately associated with size. Their relationship with man equivalent indicated consistent increases as the size of the farms increased.

Summary of Relation of Size of Business to Farm Earnings and Other Factors

In the previous pages several measures of size of business were related to farm earnings and other factors. The size factors, in the order in which they were presented, were: total capital invested; total cuerdas in farm;

TABLE 67. RELATION OF MAN EQUIVALENT TO FARM EARNINGS
240 farms, Southwestern Puerto Rico, 1942–43

Man equivalent: Range	Man equivalent: Average	Number of farms	Return on capital	Per cent return on capital	Capital turn-over	Return on labor	Labor income	Labor earn-ings
			$			$	$	$
Less than 1.5	1.0	32	159	8.9	2.70	571	229	462
1.5–1.9	1.7	36	292	10.1	2.50	962	393	661
2.0–2.9	2.4	53	367	9.5	2.46	1,284	442	786
3.0–4.9	3.9	50	1,228	12.3	2.83	2,521	1,039	1,469
5.0–9.9	7.0	41	3,348	14.6	2.96	5,465	2,497	3,122
10.0 and over	41.1	28	18,085	11.6	3.13	31,968	9,994	10,959

cuerdas in sugar cane harvested; tons of sugar cane harvested; and man equivalent. All these factors of size of business presented the same general aspects in their relation to farm earnings and other factors. In spite of the apparent repetition of facts, they all were included for discussion so as to observe significant consistencies or variations in the relationships found. An attempt is made below to summarize briefly in a general way the principal relationships which were found to exist between the size of the farms studied, their earnings and other aspects of their organization and functioning.

The results of the analysis made demonstrated that:

1. Larger farms were found to be larger in all the aspects of size studied.
2. Larger farms were found to have always the better lands, to have relatively less of their arable land cultivated, to be more specialized in sugar cane cultivation, and to be mechanized to a higher extent.
3. Large and small farms had about the same proportion of productive

and draft animals, but larger farms were found to have relatively more grazing livestock than smaller farms. Larger farms tended also to have relatively more cow-units. The quality of the productive livestock kept tended to be better for the larger farms. In general, smaller farms were found to have a larger percentage of their capital invested in livestock.

4. Larger farms had more of their lands in pasture and also more pasture per grazing livestock unit. Larger farms were found to have less of their pastures in clear permanent pastures, indicating that they had a larger proportion of seeded and harvested improved pastures.
5. Most of the irrigation equipment was found in the larger farms which, consequently, were the same ones that did practically all the irrigation carried on in the farms studied.
6. Larger farms, because of the facts that they had the better lands, that they irrigated most of their sugar cane lands, and that they applied larger amounts of units of production per cuerda of cane, obtained higher yields of sugar cane per cuerda. However, they showed to obtain lower yields per cuerda of the minor crops harvested. As to production per cow, a tendency for the larger farms to have larger yields was observed. These farms had not only more and better pastures, but also higher quality livestock.
7. Efficiency in the use of labor was found to increase with the size of farm up to a certain limit of size, beyond which it showed substantial decreases. In general, the farms with the highest labor efficiency were those ranging between $20,000 to $40,000 in total capital invested, those having between 100 to 200 total cuerdas in size, those harversting between 50 to 100 cuerdas of sugar cane and producing between 600 to 1,200 tons of cane, and those employing between 5 to 10 men during the year. In no case, were these the largest farms studied. Definitely the largest farms proved to use labor less efficiently than these farms.
8. The larger farms applied more units of production per cuerda and hired a larger proportion of the total labor employed. Smaller farms utilized more unpaid labor.
9. The larger farms derived more of their total gross income from crop sales, especially from sugar cane. They were also found to sell more of their crops harvested. The per cent income from secondary crops tended to be larger for the smaller farms. A slight tendency was also found for the larger farms to derive a larger part of their gross receipts from the sales of livestock and livestock products.
10. Size of farms was found to be definitely directly associated with farm

earnings. Net farm cash income, labor income and labor earnings showed consistent increases with increases in size. The total return on capital was found to be larger for the farms of larger size. However, the per cent return on capital was larger for the farms ranging between $5,000 to $10,000 in total capital invested, having between 60 to 100 total cuerdas in farms, harvesting between 50 to 100 cuerdas in sugar cane, producing between 300 to 600 tons of cane, and employing from 5 to 10 men during the year. As in the case of labor efficiency, none of these groups happened to be the largest. Therefore, the per cent return on the capital invested increased with size up to certain limits beyond which it showed significant declines. The capital turnover, that is, the number of years that it takes for the farm gross receipts to equalize the total capital invested, was found to be larger for the larger farms, indicating therefore that the smaller farms had more gross receipts per unit of capital invested. It may be concluded that the largest farms proved definitely to use the capital less efficiently than the smaller ones.

11. Size of farm and age of operator proved to have no relationship at all. The total population was logically found to be larger for the larger farms. The larger farms were found to be located at shorter distances from paved roads, thus, facilitating and lowering the costs of hauling and marketing farm produce.
12. In regard to the burden of mortgage indebtedness, it was found that the largest farms had a heavier total burden expressed in terms of per total cuerda in farm or as a per cent of the total farm capital, which tended to decrease with size. The most significant decline was that shown by the largest farms, indicating definitely their best economic solvency.

Relation of Intensity of Land Use to Farm Earnings and Other Factors

The intensity with which the land is used has been found to be intimately related to financial returns in farming. Of course, this aspect of farming is dependent on physical, economic, social and even on psychological factors. Many times it is subjected to political considerations and to a series of other controllable and uncontrollable factors. In addition, the ability of the farm operator to use the resources available is something that influences to a great extent the intensity with which his lands are used and, consequently, the degree of financial success he may achieve in his business.

The above section was entirely devoted to the discussion of the land classification which was made of the area studied, based on the intensity of land use. The pages to follow will be devoted to presenting the relation of

intensity of land use, as measured by five different factors, to farm earnings, and other factors of organization and operation of the farms studied. The five factors selected are: economic land class; per cent net cuerdas harvested is of total arable land; per cent cuerdas in plant-cane is of cuerdas in cane harvested; per cent area in available pasture is of total arable land, and cuerdas in available pasture per grazing livestock unit. Tables 68 to 93 presented below summarize the relationships found.

Economic Land Class

Various Size Factors. In table 68 the relation of economic land class to various size factors is presented.

Farms falling in land classes 1 and 2 were positively larger than all other farms, as measured by total cuerdas in farm, net cuerdas harvested, cuerdas in sugar cane harvested, tons of sugar cane harvested, man equivalent,

TABLE 68. RELATION OF ECONOMIC LAND CLASS TO VARIOUS SIZE FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Economic land class		Number of farms	Total cuerdas in farm	Net cuerdas harvested	Cuerdas in cane harvested	Tons of cane harvested	Man equivalent	Total capital invested	Investment in machinery and equipment
Range	Average								
1–2	1.3	40	523	180	149.5	4,013	26.6	101,100	12,677
3	3.0	116	57	30	20.0	326	3.9	9,732	400
4–5	4.8	41	163	42	6.2	136	4.8	16,800	324
6–7	6.3	43	55	24	9.1	127	3.3	6,981	224

total capital invested and investment in machinery and equipment. Considering all farms, marked tendencies for size to decrease with increases in the economic land class were observed. Tons of sugar cane harvested and investment in machinery and equipment were found to be inversely and consistently related with economic land class. That is, the farms with lands classified as better had consistently larger total production of sugar cane and larger investments in machinery and equipment. Of course, with more and better lands in sugar cane, a higher tonnage is naturally expected.

Land Use and Other Factors. The per cent of the total farm area which was arable did not show significant differences with variations in economic land class (table 69).

The per cent of the total arable land in the farms studied which was cultivated showed no relationship at all with economic land class. Very marked tendencies, however, were observed for the farms with the better lands to have done less intercropping and double-cropping practices, as

shown by the fact that higher percentages of their total area harvested were classified as net. This is explained by the fact that they also were found to have higher percentages of their net area harvested made by sugar cane, which is a year crop. Furthermore, they also had relatively less area planted in tobacco, cotton and corn. Very definitely it is demonstrated that a higher percentage of the cane on the farms with the better lands was found to be plant-cane. This practice of renewing every year between one-fourth and one-third of the total area in cane is desirable from the point of

TABLE 69. RELATION OF ECONOMIC LAND CLASS TO LAND USE AND OTHER FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Economic land class: Range	Economic land class: Average	Number of farms	Per cent land arable	Per cent of arable land harvested	Per cent total area harvested net	Per cent net harvested land in cane	Per cent cuerdas in plant cane is of total cane	Per cent total harvested land in tobacco, cotton and corn	Equipment investment per cuerda harvested
									$
1–2	1.3	40	90	38	95	83	27	11	70
3	3.0	116	92	57	84	67	8	24	13
4–5	4.8	41	81	32	66	15	13	61	8
6–7	6.3	43	88	50	83	38	6	53	9

TABLE 70. RELATION OF ECONOMIC LAND CLASS TO LIVESTOCK

240 farms, Southwestern Puerto Rico, 1942–43

Economic land class: Range	Economic land class: Average	Number of farms	Total animal units	Per cent grazing units	Per cent productive units	Per cent cow units is of productive units	Per cent investment in livestock	Average value per productive unit
								$
1–2	1.3	40	90.4	99	60	63	7	68
3	3.0	116	11.4	95	59	60	10	73
4–5	4.8	41	32.4	98	76	62	14	74
6–7	6.3	43	10.3	94	54	57	13	89

view of higher yields. The farms with the better lands, from the economic standpoint, were necessarily found to be mechanized to higher extents than those having the poorer lands.

Livestock. The per cent of the total farm capital which was constituted by livestock was found to be larger for the farms with the poorer lands, from the economic point of view (table 70). The group of farms having an economic land class of 4 and 5 had the highest percentages. These farms are located on lands which, economically, are best suited for livestock raising. The farms with the best lands had a larger total number of animal units than those having poorer lands. The latter had relatively somewhat

more productive livestock and, on the average, their value per unit was found to be higher, thus indicating that they had better animals.

Very little variation was found in the per cent that the grazing livestock was of the total animal units. Perhaps a slight tendency, if any, for the farms with the better lands to have relatively more grazing animals was observed.

Use of Pasture Land. As in the case of livestock, the farms with the best lands had the largest acreage of both available and clear permanent pasture (table 71). The farms falling in land classes 4 and 5 followed. Therefore, no consistent relationships were observed between economic land class and pastures.

The farms with the best lands had the largest number of cuerdas in available pasture per grazing livestock unit, also followed by the farms in land classes 4 and 5. The latter, however, led in the per cent of the total farm

TABLE 71. RELATION OF ECONOMIC LAND CLASS TO USE OF PASTURE LAND

240 farms, Southwestern Puerto Rico, 1942–43

Economic land class		Number of farms	Cuerdas in available pasture				Cuerdas in clear permanent pasture	
Range	Average		Total	Per grazing livestock unit	Per cent of total cuerdas in farm	Per cent of total arable land	Total	Per cent of available pasture
1–2	1.3	40	294	3.3	56	62	251	85
3	3.0	116	22	2.0	39	42	20	91
4–5	4.8	41	94	3.0	58	71	71	76
6–7	6.3	43	24	2.5	44	50	21	88

acreage which was in available pasture and in the per cent that it represented of the total arable land. This indicated a very slight tendency for the farms with the poorer lands, in general, to have relatively more land in pastures.

Irrigation. Irrigation was mostly practiced by the farms with the better lands, as shown in table 72.

Practically all the irrigation equipment was owned by the farmers operating in land classes 1 and 2. This is a very logical finding. These lands, due to the fact that they are of the highest productive quality, can economically support higher inputs per cuerda. As stated previously, irrigation equipment is of a very expensive nature. The farms falling in land classes 4 to 7 did not report investments in irrigation equipment of any kind.

Rates of Production. Rates of production, except for the secondary crops and the cows, were found to indicate tendencies of being higher for the farms falling in the best land classes (table 73).

The crop index, which includes the secondary crop only, tended to be higher for the farms located on poorer land classes. The quarts of milk produced per cow unit were also found to show the same tendency. As shown before, these farms had higher quality productive livestock. The farms located in the better land classes were found to have higher yields of sugar cane and sugar per cuerda. Previously it was demonstrated that these farms, besides having better lands, had a larger proportion of plant-

TABLE 72. RELATION OF ECONOMIC LAND CLASS TO IRRIGATION

240 farms, Southwestern Puerto Rico, 1942–43

Economic land class			Investment in irrigation equipment				Cuerdas of sugar cane irrigated		
Range	Average	Number of farms	Total	Per cuerda of cane harvested	Per cuerda of cane irrigated	Per cent of total capital	Total	Per cent of total arable land	Per cent of cane harvested
			$	$	$				
1–2	1.3	40	7,658	51	93	7.6	82.0	17.4	54.9
3	3.0	116	4	*	53	†	0.1	0.2	0.4
4–5	4.8	41	0	0	0	0.0	0.0	0.0	0.0
6–7	6.3	43	0	0	0	0.0	0.0	0.0	0.0

* Less than $0.50.

† Less than 0.05 per cent.

TABLE 73. RELATION OF ECONOMIC LAND CLASS TO RATES OF PRODUCTION

240 farms, Southwestern Puerto Rico, 1942–43

Economic land class							
Range	Average	Number of farms	Crop index (excluding sugar cane)	Tons of cane per cuerda	Tons of sugar produced per cuerda	Per cent sucrose content of cane	Quarts of milk produced per cow unit
1–2	1.3	40	94	27	3.4	12.73	789
3	3.0	116	110	16	2.1	12.85	832
4–5	4.8	41	102	22	2.8	12.78	725
6–7	6.3	43	108	14	1.8	13.00	960

cane, practiced irrigation, and, as will be shown later, applied more inputs per unit of production. The higher yields obtained, therefore, are explained.

Although no apparent relationship was found between economic land class and the sucrose content of cane, a slight tendency to increase in the farms with poorer lands was observed. This same tendency was previously noticed between size of business and sucrose content. The explanation given before applies here too.

Labor Efficiency. The efficiency with which labor was used on the farms

studied showed definitely to be related with economic land class (table 74).

Labor efficiency, when measured in terms of net cuerdas harvested per man did not show relationship with economic land class. When it was measured in terms of cuerdas in sugar cane harvested per man, tons of sugar cane per man and capital invested per man, very definite tendencies of being higher for the farms in better land classes were observed. The gross income per man, as a measure of labor efficiency showed consistent decreases as the economic land class increased. In other words, labor efficiency was higher

TABLE 74. RELATION OF ECONOMIC LAND CLASS TO LABOR EFFICIENCY

240 farms, Southwestern Puerto Rico, 1942–43

Economic land class: Range	Economic land class: Average	Number of farms	Net cuerdas harvested per man	Cuerdas in cane harvested per man	Tons of cane per man	Capital invested per man	Return on labor per man	Gross income per man
						$	$	$
1–2	1.3	40	6.8	5.6	151	3,808	831	1,266
3	3.0	116	7.7	5.2	84	2,506	658	922
4–5	4.8	41	8.8	1.3	29	3,514	541	834
6–7	6.3	43	7.2	2.7	38	2,101	571	758

TABLE 75. RELATION OF ECONOMIC LAND CLASS TO FARM EXPENSES

240 farms, Southwestern Puerto Rico, 1942–43

Economic land class			Total farm cash expenses			Hired labor expenses in sugar cane			Fertilizer costs per cuerda of cane
Range	Average	Number of farms	Per total cuerda harvested	Per net cuerda harvested	Per cent hired labor	Per cuerda of cane	Per ton of cane	Per cent of total hired labor	
			$	$		$	$		$
1–2	1.3	40	98	103	74	67	2.50	73	8
3	3.0	116	53	62	60	39	2.39	69	8
4–5	4.8	41	31	48	62	69	3.16	34	7
6–7	6.3	43	38	45	58	29	2.04	41	7

for the farms falling in better land classes than for those located in poorer lands.

Farm Expenses. The farms falling in the lower land classes, that is, those located in the better lands, were found to apply more units of production, as measured by the total farm cash expenses, both per cuerda in the farm and per cuerda harvested (table 75). Hired labor was found to be an item of expense more important for the farms falling in the better land classes, as measured by the per cent that it constituted of the total farm cash expenses.

A tendency for the hired labor expenses in sugar cane per cuerda of cane harvested to decrease as the economic land class increased was observed. This same tendency was shown again between the per cent that the hired labor expenses in sugar cane represented of the total hired labor expenses and economic land class. It was found to be larger for the farms in the better lands. No relationship was found, however, to exist between economic land class and the hired labor expenses in sugar cane per ton of cane harvested.

The expenses in fertilizer per cuerda of cane harvested were found to be lower for the farms with the poorer lands, as measured by economic land class. Apparently, the better lands were fertilized more heavily, indicating again the ability of these lands to stand, economically, larger inputs.

Farm Receipts. The farms in the lower or better land classes had higher gross receipts (table 76).

TABLE 76. RELATION OF ECONOMIC LAND CLASS TO FARM RECEIPTS

240 farms, Southwestern Puerto Rico, 1942–43

Economic land class		Number of farms	Farm gross income	Per cent income from crop sales	Per cent crop sales is of total crop value	Per cent income from cane	Per cent income from tobacco, cotton and corn	Per cent income from livestock and products
Range	Average							
			$					
1–2	1.3	40	33,618	68	99	85	3	9
3	3.0	116	3,579	61	96	72	9	9
4–5	4.8	41	3,986	51	94	27	28	3
6–7	6.3	43	2,520	60	95	41	30	2

Crop sales and economic land class showed no apparent relationship to each other. It was found that the farms in the better land classes sold more of the crops harvested than the farms in the poorer land classes. The latter consumed more of the crops grown or gave larger parts away.

The income from sugar cane was found to decrease with increases in the economic land class. That is, sugar cane is a more important source of income for the farms with the better lands. On the contrary, the per cent of the total gross receipts on these farms which was accounted for by tobacco, cotton and corn, was lower than for the farms on the poorer lands. This means that the latter relied to a larger extent on the secondary crops of the area as a source of income. The income derived from the sales of livestock and livestock products was found to be more important for the farms in the better economic land classes. This source of income, as well as sugar cane, was found to be of relatively more importance in the farms with the better lands.

Farm Earnings. Economic land class and farm earnings were found to be very closely and directly associated (table 77). This is demonstrated by the fact that the return on labor, the net farm cash income, the labor income and the labor earnings of the farms studied showed in general consistent decreases as the quality of the land, measured by economic land class, decreased. In other words, the farms in the better lands proved definitely to be financially more successful than those located in poorer lands.

From the point of view of return on capital it was found that the farms in the better land classes has the highest returns. When the return on capital was expressed as a per cent of the total capital invested, it was found that the farms in land classes 1 and 2 had the highest percentage, and those falling in land classes 4 and 5 had the lowest. The farms in the poorest land classes had a per cent return on capital which compared favorably with that of the farms located in the best lands. No significant relationship was observed between economic land class and capital turnover. The farms which showed to have the lowest capital turnover were those located in land classes 3 and 6 and 7. This demonstrated once more that the gross farm receipts per unit of capital invested were larger for the farms in the poorer lands. This is probably due to the relatively lower capital investments which these farms had.

TABLE 77. RELATION OF ECONOMIC LAND CLASS TO FARM EARNINGS

240 farms, Southwestern Puerto Rico, 1942–43

Economic land class		Number of farms	Return on capital	Per cent return on capital	Capital turnover	Return on labor	Net farm cash income	Labor income	Labor earnings
Range	Average								
			$			$	$	$	$
1–2	1.3	40	12,877	12.7	3.01	22,058	14,060	7,645	8,273
3	3.0	116	1,171	12.0	2.72	2,553	1,503	948	1,347
4–5	4.8	41	1,336	8.0	4.22	2,587	1,572	748	1,215
6–7	6.3	43	800	11.5	2.77	1,897	1,215	760	1,163

Farm Mortgage Indebtedness and Other Factors. In table 78 the relation of economic land class to farm mortgage indebtedness and other factors is presented.

No relationship was found to exist between age of operator and economic land class. The population on the farms with better lands was found to be larger than for those located on poorer lands. Definitely, better lands can support larger populations. The farms in the better land classes were consistently located at shorter distances from paved roads. This is, undoubtedly, a great advantage both from the economic and social standpoints.

Although no significant relationship was found between economic land class and farm mortgage indebtedness, the farms located in the extreme land classes had the lowest farm mortgage burden when expressed as a per cent of the total farm capital. This is due to the fact that the farmers in the best lands had, on the average, a greater economic solidity, and those on the poorer land classes are not only very suspicious of long-term credit but also present great risks to this type of agency.

Per Cent Net Cuerdas Harvested Is of Total Arable Land

The per cent that the net cuerdas harvested represents of the total arable land in the farms studied was related to farm earnings and other factors. The results are presented in tables 79 to 85. This factor measures to a certain extent the intensity with which the arable lands in the area studied are

TABLE 78. RELATION OF ECONOMIC LAND CLASS TO FARM MORTGAGE INDEBTEDNESS AND OTHER FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Economic land class		Number of farms	Age of operator	Farm population	Distance to nearest paved road (kms.)	Farm mortgage indebtedness		
Range	Average					Total	Per total cuerda in farm	Per cent of total capital
						$	$	
1–2	1.3	40	48	46	0.5	3,744	7	4
3	3.0	116	49	16	0.9	597	10	6
4–5	4.8	41	51	32	1.0	1,383	8	8
6–7	6.3	43	49	15	1.2	289	5	4

utilized for crop-growing. Of course, the utilization of the land in pasture is excluded from consideration here.

Various Size Factors. In table 79, the relationship of per cent net cuerdas harvested is of total arable land to various size factors is presented.

No consistent relationships between the per cent that the net cuerdas harvested represented of the total arable land and size were observed. It was observed, however, that the group of farms which harvested less than 35 per cent of their total arable land were consistently the largest in size as measured by total cuerdas in farm, net cuerdas harvested, cuerdas in sugar cane harvested, tons of sugar cane harvested, man equivalent, total capital invested, and investment in machinery and equipment. On the other hand, the smallest farms, as measured by the above same factors, had consistently the largest percentages except when size was measured by tons of sugar cane produced. It is also worth mentioning that the farms in the group which ranged between 50 and 64 per cent, showed marked tendencies

to be rather small in size. In spite of this apparent inconsistency, a clear tendency was observed for the smaller farms to utilize more of their arable lands in crop-growing.

Land Use and Other Factors. A very definite inverse relationship was found to exist between the per cent of the total arable land which was har-

TABLE 79. RELATION OF PER CENT NET CUERDAS HARVESTED IS OF TOTAL LAND TO VARIOUS SIZE FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent net cuerdas harvested is of total arable land: Range	Average	Number of farms	Total cuerdas in farm	Net cuerdas harvested	Cuerdas in cane harvested	Tons of cane harvested	Man equivalent	Total capital invested	Investment in machinery and equipment
								$	$
Less than 35	23	38	486	96	64.5	1,944	15.9	65,621	10,435
35–49	42	37	222	81	52.9	1,219	12.1	43,603	2,286
50–64	58	39	67	35	18.8	308	4.2	10,431	574
65–79	73	45	85	59	44.0	961	6.9	20,122	1,186
80–94	86	48	57	43	25.8	494	4.7	11,708	386
95 and over	98	33	25	22	17.8	347	3.1	5,476	30

TABLE 80. RELATION OF PER CENT NET CUERDAS HARVESTED IS OF TOTAL ARABLE LAND TO LAND USE AND OTHER FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent net cuerdas harvested is of total arable land: Range	Average	Number of farms	Economic land class	Per cent land arable	Per cent of arable land harvested	Per cent net harvested land in cane	Per cent total harvested land in tobacco, cotton and corn	Equipment investment per cuerda harvested
								$
Less than 35	23	38	4.2	88	86	67	25	109
35–49	42	37	4.2	86	88	65	30	28
50–64	58	39	3.7	92	74	54	38	16
65–79	73	45	3.5	95	91	75	17	20
80–94	86	48	3.3	89	86	59	28	9
95 and over	98	33	2.9	92	90	81	19	1

vested and the economic land class (table 80). It was found that the farms with the better lands showed consistently to utilize more of their arable lands in crops. This shows that, apparently, the better lands are put into crops while the poorer ones are left to other uses. Definitely, this is a very wise farming practice, considering the general economy of the area under study.

The extent to which the arable land in the farms studied was cultivated, did not show to be related with either the per cent land arable, the amount of doublecropping and intercropping done as measured by the per cent the net area harvested is of the total area harvested, the per cent of the net area harvested which was in cane, nor with the per cent of the total area harvested which was represented by cuerdas in tobacco, cotton and corn. It was found, however, that the farms which cultivated more of their total arable land were mechanized to a lower extent than those which cultivated less of their arable land. It should be remembered here that, in general, they also were found to be the smaller in size.

Livestock. In table 81 it is attempted to present the relationships found between the extent to which the arable lands in the farms studied were cropped and the livestock kept on those farms.

TABLE 81. RELATION OF PER CENT NET CUERDAS HARVESTED IS OF TOTAL ARABLE LAND TO LIVESTOCK

240 farms, Southwestern Puerto Rico, 1942-43

Per cent net cuerdas harvested is of total arable land: Range	Average	Number of farms	Total animal units	Per cent grazing units	Per cent productive units	Per cent cow units is of productive units	Per cent investment in livestock	Average value per productive unit
								$
Less than 35	23	38	82.3	99	65	62	9	73
35–49	42	37	50.0	99	71	64	9	70
50–64	58	39	14.5	94	55	52	11	65
65–79	73	45	13.9	96	45	56	6	66
80–94	86	48	10.0	96	54	62	8	90
95 and over	98	33	1.9	83	74	48	2	66

The total animal units kept on the farms as well as the per cent which was grazing livestock showed a decline with increases in the per cent of the arable land which was cropped. In other words, the farms which grew relatively more crops had less animals and, furthermore, less of the grazing type. Obviously, less land was available to take care of the livestock enterprise.

No relationship was found to exist between the proportion of arable land cropped and the per cent of the livestock kept that was of the productive type. The average value per productive animal unit, which indicates to some extent its quality, also showed no relationship. The relative importance of dairy cows tended to decrease as the farms used more of their arable lands in crops. In general, the per cent of the total farm capital which was accounted for by the livestock kept on the farm, decreased as more arable land was cultivated. To summarize, the more arable land cropped, the less the importance of the livestock enterprise on the farms studied.

Use of Pasture Land. Since the livestock enterprise is of relatively less importance on the farms which had more of their arable land in crops, it was very reasonable to find that the total number of cuerdas in available pasture as well as in clear permanent pasture decreased as the farms had relatively more arable land in crops (table 82).

The number of cuerdas in available pasture per grazing livestock unit in the farm was found, logically, to be larger for the farms with a lower percentage of their arable lands cultivated. Inverse consistent relationships were also found between the per cent net cuerdas harvested is of total arable land and the per cent that the available pasture represented of both the total cuerdas in farm and the total arable land. That is, they decreased consistently as more of the arable land was cropped. The farms with higher percentages of their arable land cultivated were also found to have more

TABLE 82. RELATION OF PER CENT NET CUERDAS HARVESTED IS OF TOTAL ARABLE LAND TO USE OF PASTURE LAND

240 farms, Southwestern Puerto Rico, 1942–43

Per cent net cuerdas harvested is of total arable land		Number of farms	Cuerdas in available pasture				Cuerdas in clear permanent pasture	
Range	Average		Total	Per grazing live-stock unit	Per cent of total cuerdas in farm	Per cent of total arable land	Total	Per cent of avail-able pasture
Less than 35	23	38	321	3.9	66	75	264	82
35–49	42	37	116	2.4	52	61	102	88
50–64	58	39	27	2.0	41	44	24	89
65–79	73	45	24	1.8	28	30	21	88
80–94	86	48	12	1.2	21	24	11	92
95 and over	98	33	1	0.9	6	6	1	100

of their total available pasture accounted for by clear permanent pasture. This shows that, conversely, they had less improved seeded and harvested pastures.

Irrigation. Most of the irrigation found to be practiced in the farms studied was done by the farms which had lower percentages of their total arable land cultivated (table 83).

A very marked tendency for the farmers with more of their arable land cultivated to own more of the irrigation equipment was observed. Consequently, they also carried on irrigation practices to a larger extent. As was previously shown these farms were also found to be larger in size.

Rates of Production and Labor Efficiency. In table 84 the relationship of per cent net cuerdas harvested is of total arable land to rates of production and labor efficiency is presented.

The yields of the secondary crops of the area, as measured by the crop

index (excluding sugar cane) showed a tendency to be larger for the farms which cultivated higher percentages of their arable lands. The yields of sugar cane per cuerda measured in tons, on the contrary, were found to be larger for the farms which had less of their arable land in crops. As to the

TABLE 83. RELATION OF PER CENT NET CUERDAS HARVESTED IS OF TOTAL ARABLE LAND TO IRRIGATION

240 farms, Southwestern Puerto Rico, 1942–43

Per cent net cuerdas harvested is of total arable land			Investment in irrigation equipment				Cuerdas of sugar cane irrigated		
Range	Average	Number of farms	Total	Per cuerda of cane harvested	Per cuerda of cane irrigated	Per cent of total capital	Total	Per cent of total arable land	Per cent of cane harvested
			$	$	$				
Less than 35	23	38	6,929	107	132	10.6	52.3	12.3	81.1
35–49	42	37	695	13	33	1.6	20.8	10.8	39.3
50–64	58	39	64	3	53	0.6	1.2	2.0	6.4
65–79	73	45	328	7	33	1.6	10.1	12.5	22.9
80–94	86	48	12	1	24	0.1	0.5	1.0	1.9
95 and over	98	33	0	0	0	0.0	0.3*	1.3	1.7

* Irrigated with outside equipment.

TABLE 84. RELATION OF PER CENT NET CUERDAS HARVESTED IS OF TOTAL ARABLE LAND TO RATES OF PRODUCTION AND LABOR EFFICIENCY

240 farms, Southwestern Puerto Rico, 1942–43

Per cent net cuerdas harvested is of total arable land											
Range	Average	Number of farms	Crop index (excluding cane)	Tons of cane per cuerda	Quarts of milk per cow unit	Net cuerdas harvested per man	Cuerdas in cane harvested per man	Tons of cane per man	Capital invested per man	Return on labor per man	Gross income per man
									$	$	$
Less than 35	23	38	89	30	876	6.1	4.1	123	4,139	680	1,174
35–49	42	37	105	23	705	6.7	4.4	101	3,618	719	1,053
50–64	58	39	115	16	751	8.4	4.5	73	2,490	710	967
65–79	73	45	118	22	655	8.5	6.4	139	2,921	844	1,130
80–94	86	48	94	19	751	9.2	5.4	104	2,467	802	1,082
95 and over	98	33	116	19	822	7.2	5.8	112	1,775	743	983

production of milk per cow, it was found to have no significant relationship to the per cent of the arable land which was harvested.

No consistent changes in the labor efficiency were observed among the farms studied with changes in the per cent that the net cuerdas harvested represented of the total arable land. The only exception was in the case of capital invested per man. It was found to decrease consistently as the

proportion of the arable land cultivated increased. The net cuerdas harvested per man were found to increase up to the group of farms which reported having cropped between 80 to 90 per cent of their total arable land. The group of farms above the latter showed a decline. The same tendency of going up and then declining beyond a certain limit was also observed when labor efficiency was measured in terms of cuerdas in sugar cane harvested per man. The farms with the top efficiency were found to be those which cropped between 65 to 79 per cent of their total arable land. They were also found to have the highest sugar cane tonnage per man and the highest return on labor per man. The gross income per man showed insignificant variations; however, the farms with less than 35 per cent of their arable lands cropped had the highest gross income per man.

TABLE 85. RELATION OF PER CENT NET CUERDAS HARVESTED IS OF TOTAL ARABLE LAND TO FARM EARNINGS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent of net cuerdas harvested is of total arable land: Range	Average	Number of farms	Return on capital	Per cent return on capital	Capital turnover	Return on labor	Labor income	Labor earnings
						$	$	$
Less than 35	23	38	5,509	8.4	3.53	10,778	2,120	2,753
35–49	42	37	5,072	11.6	3.44	8,664	3,146	3,751
50–64	58	39	1,349	12.9	2.57	2,975	1,173	1,705
65–79	73	45	3,236	16.1	2.58	5,814	2,481	2,927
80–94	86	48	2,196	18.8	2.28	3,807	1,845	2,175
95 and over	98	33	1,195	21.8	1.81	2,291	1,097	1,288

The relationships found here are perhaps mostly due to the influence of size of business. As shown previously, the farms with the higher percentages of their arable lands harvested were found to show tendencies of being larger in size. Consequently, the relationships observed here compare very favorably with those found between size of business and labor efficiency and rates of production.

Farm Earnings. Per cent net cuerdas harvested is of total arable land and farm earnings were related and the results presented in table 85.

The return on capital showed tendencies to decrease with increases in the per cent of the land arable which was cropped. The relationship found was not very consistent. However, when the return on capital was expressed as a per cent of the total capital invested, a direct and very close association was found with the per cent that the net acreage harvested constituted of the total arable land. These two factors proved to be very closely associated. That is, the more arable land cultivated, the higher the per cent

return on capital. Similarly, the capital turnover was also found to decrease consistently. In other words, it takes less number of years on the farms with more of their arable land cropped for their gross receipts to equalize the total farm capital. Evidently, from the capital investment standpoint, it was economically advisable to cultivate larger proportions of the total arable land.

Labor income did not show to be too much associated with the per cent that the net cuerdas harvested is of the total arable land. The farms which cropped between 35 to 49 per cent of their total arable acreage had the highest labor income and labor earnings. In general, labor income, labor earnings and return on labor tended to be lower for the farms which had higher percentages of their arable land cultivated.

TABLE 86. RELATION OF PER CENT CUERDAS IN PLANT-CANE IS OF CUERDAS IN CANE HARVESTED TO VARIOUS FACTORS OF FARM ORGANIZATION

186 farms, Southwestern Puerto Rico, 1942–43

Per cent cuerdas in plant-cane is of cuerdas in cane harvested: Range	Average	Number of farms	Cuerdas in cane harvested	Tons of cane harvested	Tons of sugar produced	Animal units	Per cent workstock is of total animal units	Economic land class
0	0	126	18.5	314	41.1	12.7	36	3.5
Less than 15	10	18	91.7	2,018	259.7	35.7	43	2.3
15–29	20	22	102.2	2,443	307.4	55.8	33	3.3
30 and over	45	20	135.6	3,989	505.1	100.3	43	2.4

Per Cent Cuerdas in Plant-Cane Is of Cuerdas in Cane Harvested

As was indicated before, the practice of renewing every year part of the cane by planting new cane is desirable from the point of view of yields. The extent to which a farmer carries on this practice may be an indication, besides other things, of the intensity with which he cultivates his sugar cane lands. In tables 86 to 88 presented below, it is attempted to show the relation of per cent cuerdas in plant-cane is of cuerdas in cane harvested to various factors of farm organization and functioning and to farm earnings. Only 186 farms found to grow sugar cane were included.

Various Factors of Farm Organization. The per cent that the cuerdas in new or plant-cane represented of the total cuerdas in cane harvested was related to various factors of farm organization. The results are presented in table 86.

The size of the farm business, as measured by cuerdas in sugar cane harvested, tons of sugar cane harvested, tons of sugar produced and animal

units, was found to increase consistently with increases in the per cent of the sugar cane harvested which was plant-cane. This means that the larger the farm, the more plant-cane they harvested. The larger the extent to which this practice is carried on, the larger the expenditures, as will be shown later. Therefore, this practice can better be afforded by the larger farmers who, generally, have a more solid economic position.

The extent to which this practice was carried on had nothing to do with the amount of work-stock available on the farms studied. This is shown by the fact that no relationship was found to exist between the extent to which this practice was carried on and the per cent of the total animal units accounted for by work-stock animals.

A very clear tendency was observed which indicated that the economic land class was lower as the practice of harvesting more plant-cane was intensified. In other words, the better the lands the more intensively this

TABLE 87. RELATION OF PER CENT CUERDAS IN PLANT-CANE IS OF CUERDAS IN CANE HARVESTED TO VARIOUS FARM EXPENSES

186 farms, Southwestern Puerto Rico, 1942–43

Per cent cuerdas in plant-cane is of cuerdas in cane harvested: Range	Average	Number of farms	Total expenses in hired labor	Per cent hired labor expenses in cane	Hired labor expenses in cane per cuerda	Hired labor expenses in cane per ton	Fertilizer costs per cuerda of cane
			$		$	$	$
0	0	126	1,110	65	39	2.29	7
Less than 15	10	18	6,067	79	52	2.36	8
15–29	20	22	8,174	74	59	2.47	8
30 and over	45	20	14,803	72	78	2.65	8

practice was followed. Naturally, the better lands can stand, economically, more inputs per cuerda.

Various Farm Expenses. Table 87 shows the relation of per cent cuerdas in plant-cane is of cuerdas in cane harvested to various farm expenses.

The total expenses in hired labor were found to increase consistently with increases in the relative importance of the plant-cane harvested. No significant relationship was observed, however, between the per cent that the hired labor expenses in sugar cane represented of the total hired labor expenses, and the extent to which the practice of harvesting more plant-cane was intensified. Perhaps, a very slight tendency of being directly related was noticed, but the variations found cannot be considered significant. Both the hired labor expenses in sugar cane per cuerda and per ton of cane produced were found to increase with increases in the per cent of the total sugar cane acreage harvested which was plant-cane. This shows definitely that this practice is very closely associated with larger inputs per cuerda.

Although the fertilizer expenses per cuerda of cane harvested tended to increase, the differences found cannot be described as significant.

Rates of Production and Farm Earnings. Sugar cane yields were definitely found to increase with increases in the per cent of the total cane acreage harvested which was plant-cane (table 88).

The tons of sugar cane as well as of sugar produced per cuerda were found to increase consistently as the relative importance of the plant-cane harvested increased. As to the per cent sucrose content of cane, a very marked tendency to decrease was observed. It is perhaps advisable that further research on this observation should be undertaken.

Apparently the value of the additional tonnage of sugar cane which resulted from the practice of having higher proportions of the cane renewed, were not sufficiently high, beyond certain limits, to compensate economically for the added costs of the larger inputs applied. The net farm cash income increased almost consistently with intensification of this practice; however, labor income and labor earnings did not show this same relationship. The lowest labor income and labor earnings were reported by the farms which did not follow this farm practice. The highest were reported by the group of farms which had up to 15 per cent of the cane harvested in plant-cane. Beyond this point substantial decreases in both labor income and labor earnings were recorded.

TABLE 88. RELATION OF PER CENT CUERDAS IN PLANT-CANE IS OF CUERDAS IN CANE HARVESTED TO RATES OF PRODUCTION AND FARM EARNINGS

186 farms, Southwestern Puerto Rico, 1942–43

Per cent cuerdas in plant-cane is of cuerdas in cane harvested		Number of farms	Tons of cane per cuerda	Tons of sugar per cuerda	Per cent sucrose content of cane	Net farm cash income	Labor income	Labor earnings
Range	Average							
						$	$	$
0	0	126	17	2.2	13.10	1,726	1,125	1,526
Less than 15	10	18	22	2.8	12.87	8,718	6,376	6,975
15–29	20	22	24	3.0	12.58	8,328	4,790	5,442
30 and over	45	20	29	3.7	12.66	11,734	4,397	4,934

To conclude, the farm practice of increasing plant-cane acreage is apparently desirable from the point of view of yields, but its intensification is definitely limited to certain extents by economic considerations. Therefore, it is advisable that it be carefully followed.

Cuerdas in Available Pasture Per Grazing Livestock Unit

The number of cuerdas of pasture available for each unit of grazing livestock in the farms studied is, to a large extent, a measure of the intensity

with which the pasture lands were utilized in Southwestern Puerto Rico. It is also, though not exactly, an indication of the carrying capacity of the pastures of the area. In the tables 89 to 93 below, it is attempted to show how it is related to farm earnings and other factors of farm organization and operation.

TABLE 89. RELATION OF CUERDAS IN AVAILABLE PASTURE PER GRAZING LIVESTOCK UNIT TO VARIOUS SIZE FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Cuerdas in available pasture per grazing livestock unit		Number of farms	Total cuerdas in farm	Net cuerdas harvested	Cuerdas in cane harvested	Man equivalent	Total capital invested
Range	Average						
							$
Less than 1.0	0.7	77	31	24	17.1	3.5	7,187
1.0–1.9	1.7	60	121	57	40.0	7.8	26,388
2.0–2.9	2.4	52	140	62	34.1	7.0	20,973
3.0–3.9	3.5	29	223	59	35.7	8.0	34,479
4.0 and over	4.8	22	598	151	110.2	23.5	87,941

TABLE 90. RELATION OF CUERDAS IN AVAILABLE PASTURE PER GRAZING LIVESTOCK UNIT TO LAND USE

240 farms, Southwestern Puerto Rico, 1942–43

Cuerdas in available pasture per grazing livestock unit		Number of farms	Economic land class	Per cent land arable	Per cent net area harvested is of total arable land	Cuerdas in sugar cane harvested	
Range	Average					Per cent of total arable land	Per cent of net cuerdas harvested
Less than 1.0	0.7	77	3.3	94	80	58	73
1.0–1.9	1.7	60	3.5	85	55	39	70
2.0–2.9	2.4	52	3.9	81	54	30	55
3.0–3.9	3.5	29	3.7	90	30	18	60
4.0 and over	4.8	22	4.2	93	27	20	73

Various Size Factors. It was definitely found that the larger the size of the farm business the larger the area they had in available pasture per grazing livestock unit kept on the farm (table 89).

The total farm acreage, the net cuerdas harvested, the cuerdas in sugar cane harvested, the number of men employed during the year, and the total capital invested, in general, increased consistently with increases in the number of cuerdas in available pasture per grazing livestock unit.

Land Use. The economic land class was found to increase consistently as the acreage of pasture available per grazing livestock unit increased (table 90). That is, the farms with the better lands were found to have less

pasture available per grazing animal unit than the farms located in the poorer lands. Very probably, the farmers found through experience that more profitable results could be obtained by cultivating better lands more intensively rather than leaving them in pasture for livestock raising.

The per cent of the farm acreage which was arable did not show any relationship with cuerdas in available pasture per grazing livestock unit. However, the proportion of that arable land which was cultivated showed a relation which indicated a marked tendency of decreasing with increases in the amount of pasture per grazing animal unit. Apparently this reason may explain the larger amount of arable land left in pasture and consequently the larger amount of pasture available per grazing livestock unit.

The per cent of the total arable land which was used in sugar cane was inversely related to the cuerdas in available pasture per grazing livestock unit. In other words, they decreased as the area in available pasture per grazing livestock unit increased. However, the per cent that the cuerdas in sugar cane harvested represented of the net cuerdas harvested showed no relationship with the amount of pasture available per grazing animal unit.

TABLE 91. RELATION OF CUERDAS IN AVAILABLE PASTURE PER GRAZING LIVESTOCK UNIT TO LIVESTOCK

240 farms, Southwestern Puerto Rico, 1942–43

Cuerdas in available pasture per grazing livestock unit: Range	Average	Number of farms	Total animal units	Per cent grazing units	Per cent productive units	Per cent cow units is of productive units	Per cent investment in livestock	Average value per Productive unit
								$
Less than 1.0	0.7	77	7.9	94	57	61	10	90
1.0–1.9	1.7	60	30.3	97	69	61	9	64
2.0–2.9	2.4	52	23.6	97	66	62	9	71
3.0–3.9	3.5	29	42.3	99	75	60	11	84
4.0 and over	4.8	22	83.5	99	50	65	6	64

Livestock. Although the total animal units in the farms studied were found to increase as the amount of pasture available per grazing livestock unit increased, the per cent which was constituted by grazing livestock showed but a very slight tendency, if any, to increase. Practically no variation was found (table 91). The per cent of the total farm livestock which was classified as productive was not related to the cuerdas in available pasture per grazing livestock unit. Furthermore, the proportion of the productive animal units which was constituted by dairy cows showed also to have no relation. Just a very slight tendency for the per cent of the total farm capital accounted for by livestock to decrease as the area in pasture available per grazing animal unit increased, was observed. The same de-

creasing tendency was observed in the case of the average value per productive animal unit.

Use of Pasture Land. In table 92, the relation of cuerdas in available pasture per grazing livestock unit to use of pasture land is presented.

Both the total cuerdas in available pasture and in clear permanent pasture were found to show consistent increases with increases in the cuerdas in

TABLE 92. RELATION OF CUERDAS IN AVAILABLE PASTURE PER GRAZING LIVESTOCK UNIT TO USE OF PASTURE LAND

240 farms, Southwestern Puerto Rico, 1942–43

Cuerdas in available pasture per grazing livestock unit: Range	Average	Number of farms	Cuerdas in available pasture: Total	Per cent of total cuerdas in farm	Per cent of total arable land	Cuerdas in clear permanent pasture: Total	Per cent of available pasture.
Less than 1.0	0.7	77	6	18	19	4	67
1.0–1.9	1.7	60	49	40	47	44	90
2.0–2.9	2.4	52	54	39	47	49	91
3.0–3.9	3.5	29	148	66	74	122	82
4.0 and over	4.8	22	399	67	72	325	81

TABLE 93. RELATION OF CUERDAS IN AVAILABLE PASTURE PER GRAZING LIVESTOCK UNIT TO RATES OF PRODUCTION, LABOR EFFICIENCY AND FARM EARNINGS

240 farms, Southwestern Puerto Rico, 1942–43

Cuerdas in available pasture per grazing livestock unit: Range	Average	Number of farms	Quarts of milk per cow unit	Net cuerdas harvested per man	Cuerdas in cane harvested per man	Capital invested per man	Gross income per man	Capital turnover	Labor income	Labo earnings
						$	$		$	$
Less than 1.0	0.7	77	822	6.7	4.9	2,058	1,016	2.03	1,244	1,530
1.0–1.9	1.7	60	677	7.2	5.1	3,367	1,009	3.34	1,763	2,275
2.0–2.9	2.4	52	717	8.8	4.9	3,000	1,082	2.77	2,362	2,894
3.0–3.9	3.5	29	1,044	7.4	4.5	4,319	1,198	3.60	3,020	3,559
4.0 and over	4.8	22	756	6.4	4.7	3,741	1,186	3.16	3,052	3,659

available pasture per grazing livestock unit. However, the per cent of the total available pasture represented by the clear permanent pasture showed no indication of being related. On the other hand, the per cent that the area in available pasture represented of both the total farm acreage and of the total arable land, showed marked and definite tendencies to increase as the area in available pasture per grazing livestock unit increased. With no relative change in the amount of grazing livestock, as shown before, and an

increase in the relative amount of pasture, the logical result was, therefore, a larger acreage of available pasture per grazing animal unit.

Rates of Production, Labor Efficiency, and Farm Earnings. The relation of cuerdas in available pasture per grazing livestock unit to rates of production, labor efficiency, and farm earnings is presented in table 93.

No apparent relationships were found to exist between quarts of milk produced per cow unit and the cuerdas in available pasture per grazing livestock unit.

The labor efficiency, when measured in terms of net cuerdas harvested per man, and of cuerdas in sugar cane harvested per man, showed no relationship at all. A tendency to increase, however, was observed when it was measured in terms of both capital invested and gross income per man.

The capital turnover was found to show definite tendencies of increasing with increases in the cuerdas in available pasture per grazing livestock unit. That is, it takes less years for the gross receipts, which the farms with the lower acreages of available pasture per grazing livestock unit obtained in the crop year 1942–43, to equalize the total farm capital. Both labor income and labor earnings showed consistent increases with increases in the number of cuerdas of pasture available per unit of grazing stock. The farms with more pasture per grazing livestock unit were found to be larger in size; and therefore, the reasons which accounted for the larger returns on the larger farm businesses apply here, too.

Summary of Relation of Intensity of Land Use to Farm Earnings and Other Factors

In the preceding pages, the different relationships of intensity of land use to farm earnings and other factors were presented. Among several measures, only four, which were considered to be of more significance, were selected; namely, economic land class, per cent net cuerdas harvested is of total arable land, per cent cuerdas in plant-cane is of cuerdas in cane harvested and cuerdas in available pasture per grazing livestock unit. Many different relationships were found out of which some were considered to be more significant. A general summary of the most important findings is herewith presented:

1. The farms falling in the better land classes and which cultivated them more intensively were found to be larger in size.
2. The farms in the better lands were found to use less of the total arable land in crops, but the intensity with which the land in crops was used was larger as shown by the fact that they had relatively more sugar cane, more plant-cane, less secondary crops, less productive animals, and more farm machinery.
3. The farms in the poorer land classes were found to have relatively

more lands in pasture. Consequently, the relative importance of the livestock enterprise was larger for these farms.

4. Irrigation practices were carried on mostly by the farms located in the better lands.
5. Sugar cane yields were found to be higher for the farms falling in the better lands; however, these located in poorer lands showed to have better yields in the secondary crops grown.
6. Labor efficiency was also observed to be higher for the farms which used their lands more intensively, that is, those located in the better lands. The farms cultivating between 65 to 79 per cent of the total arable land led in labor efficiency. Beyond this point it decreased substantially.
7. The farms in the better lands were found to apply more inputs per cuerda, as shown by higher farm cash expenses, larger amounts of hired labor, and higher amounts of fertilizer used.
8. Sugar cane was a more important source of income for the farms with the better lands.
9. The farms on the lands which were used more intensively proved definitely to be financially more successful than those located in poorer lands.
10. The practice of increasing plant-cane acreage proved to be desirable from the point of view of yields, but its intensification is definitely limited to certain extents by economic considerations. The highest returns were obtained by the farms which had up to 15 per cent of the cane harvested in plant-cane.
11. Intensity of land use was not found to be related to age of operator.
12. Farms in the better land classes were found to be supporting larger farm population.
13. The farms in the better lands were consistently located at shorter distances from paved roads.
14. The farms located in the extreme land classes were found to have the lowest farm mortgage burden. This is due to the fact that the farmers in the best lands had a greater economic solidity, and those in the poorer land classes are not only very suspicious of long-term credit but also present greater risks to this type of agency.

Relation of Rates of Production to Farm Earnings and Other Factors

Another important factor affecting farm profits is rates of production. The general principle is that higher rates of production, within limits, bring higher returns. The reason is that it costs more per acre or per productive animal to obtain higher yields or production but not per unit of

output. Within the limits of farmers' practices, costs increase at slower rates than returns.

There are definite limits to yields. It should be kept in mind that farmers are dealing with living things and that weather conditions are beyond their control. Besides these physical limitations, there are also definite economic limitations. As an example is the principle of diminishing returns. As increasing amounts of one factor of production are added to a fixed quantity of other factors, the amount of product increases at a decreasing rate. Also profits increase at a decreasing rate until a point may be reached beyond which it is uneconomical to apply added quantities of a factor of production. Changes in the price of the product may cause this optimum point to fluctuate. It is also true that in agriculture, as well as in other industries, an item of cost cannot be increased without increasing some of the others.

Good land and good animals are very important in increasing yields; but the farmers' individual problem is to get the best proportion of the factors of production with which they are working such as price of product, price of land, productivity of the land, quality of the animals, cost of labor, price of feed, price of fertilizer, price of other cost items, the amount of money at his disposal, etc. He should also correct adverse conditions limiting yields by relatively cheap methods.

Tons of Sugar Cane per Cuerda

In tables 94 to 99 presented below, it is attempted to present the relation of tons of sugar cane per cuerda to farm earnings and various other factors. The fact that sugar cane was the leading crop in the area and that it was cultivated in the great majority of the farms studied makes of this factor an excellent measure of the rates of production of crops in the area studied. For the purpose of studying relationships only the information on the 186 farms which planted sugar cane during the crop year studied was included.

Various Size Factors. Tons of sugar cane produced per cuerda was found to be directly associated with size of business (table 94).

The size of the farms studied, as measured by total cuerdas in farm, net cuerdas harvested, cuerdas in sugar cane harvested, tons of sugar cane harvested, tons of sugar cane produced, man equivalent and total capital invested, increased consistently as the yield of sugar cane per cuerda increased.

Land Use and Other Factors. The farms with the higher yields of sugar cane per cuerda were found to be located in the better land classes (table 95). A very definite direct relationship was found between the two factors. That is, the farms with the better lands had the better yields.

No association was observed, however, between the per cent land arable and sugar cane yields. The proportion of the total arable land which was harvested showed, on the contrary, a marked tendency to decrease as the yields of cane increased. The farms with the higher sugar cane yields had consistently larger percentages of the net cuerdas harvested in sugar cane. In other words, they were specialized to a higher extent on sugar cane

TABLE 94. RELATION OF TONS OF SUGAR CANE PER CUERDA TO VARIOUS SIZE FACTORS

186 farms, Southwestern Puerto Rico, 1942–43

Tons of sugar cane per cuerda: Range	Tons of sugar cane per cuerda: Average	Number of farms	Total cuerdas in farm	Net cuerdas harvested	Cuerdas in cane harvested	Tons of cane harvested	Tons of sugar produced	Man equivalent	Total capital invested
									$
10 and less	8	24	62	36	16.0	131	15.9	3.6	8,975
11–15	13	47	68	38	25.6	344	45.0	4.1	10,213
16–20	17	66	141	46	31.9	549	70.3	5.8	19,968
21–25	23	29	143	60	42.5	983	124.9	8.5	27,283
26 and over	31	20	638	229	201.1	6,265	798.3	37.4	134,870

TABLE 95. RELATION OF TONS OF SUGAR CANE PER CUERDA TO INTENSITY OF LAND USE AND OTHER FACTORS

186 farms, Southwestern Puerto Rico, 1942–43

Tons of sugar cane per cuerda: Range	Tons of sugar cane per cuerda: Average	Number of farms	Economic land class	Per cent land arable	Per cent of arable land harvested	Per cent net harvested land in cane	Per cent cuerdas in plant cane is of total cane	Per cent investment in machinery and equipment
10 and less	8	24	4.0	92	63	44	10	5
11–15	13	47	3.6	93	59	68	6	3
16–20	17	66	3.3	84	38	70	16	4
21–25	23	29	2.8	90	46	71	21	3
26 and over	31	20	2.0	89	40	88	28	17

growing. These farms also showed definite tendencies of having relatively larger acreages of plant-cane. The farms with higher yields of sugar cane, in addition, were found to be mechanized to a larger extent. Therefore, better lands, more plant-cane and probably better cultivation practices aided by more and better machinery contributed largely to the higher yields.

Irrigation. In table 96 below, it is demonstrated that the farms with higher yields of sugar cane per cuerda practiced irrigation to a larger extent than those which had lower yields of cane.

The investment in irrigation equipment, as well as the acreage of sugar cane irrigated was found to be larger, both expressed in absolute and relative amounts, for the farms with higher yields of sugar cane per cuerda. This fact is an additional reason which accounted for the higher yields of cane obtained.

TABLE 96. RELATION OF TONS OF SUGAR CANE PER CUERDA TO IRRIGATION

186 farms, Southwestern Puerto Rico, 1942–43

Tons of sugar cane per cuerda		Number of farms	Investment in irrigation equipment				Cuerdas of sugar cane irrigated		
Range	Average		Total	Per cuerda of cane harvested	Per cuerda of cane irrigated	Per cent of total capial	Total	Per cent of total arable land	Per cent of cane harvested
			$	$	$				
10 and less	8	24	20	1	53	0.2	0.4	0.6	2.3
11–15	13	47	0	0	0	0.0	0.0	0.0	0.0
16–20	17	66	115	4	28	0.6	4.2	3.5	13.0
21–25	23	29	99	2	14	0.4	6.9	5.3	16.2
26 and over	31	20	14,792	74	105	11.0	140.4	24.7	69.8

TABLE 97. RELATION OF TONS OF SUGAR CANE PER CUERDA TO OTHER RATES OF PRODUCTION AND LABOR EFFICIENCY

186 farms, Southwestern Puerto Rico, 1942–43

Tons of sugar cane per cuerda		Number of farms	Tons of sugar per cuerda	Per cent sucrose content of cane	Tons of cane per man	Net cuerdas harvested per man	Cuerdas in cane harvested per man	Capital invested per man	Gross income per man
Range	Average								
								$	$
10 and less	8	24	1.0	12.09	36	9.9	4.4	2.465	733
11–15	13	47	1.8	13.06	84	9.2	6.3	2,500	929
16–20	17	66	2.2	12.81	95	7.9	5.5	3,443	1,071
21–25	23	29	2.9	12.70	115	7.0	5.0	3,192	1,197
26 and over	31	20	4.0	12.74	168	6.1	5.4	3,608	1,258

Other Rates of Production and Labor Efficiency. Thus tons of sugar produced per cuerda were found to increase consistently as the tons of sugar cane per cuerda increased (table 97). This was solely the effect of higher tonnage since no relationship was found between tons of sugar cane per cuerda and the per cent sucrose content of cane.

The labor efficiency, measured in terms of tons of sugar cane per man, capital invested per man and gross income per man, in general was found to increase consistently as the yields of sugar cane per cuerda increased. However, when it was expressed in terms of net cuerdas harvested per man,

consistent decreases were observed with increases in the tons of sugar cane per cuerda. The number of cuerdas in sugar cane harvested per man showed no relationship with sugar cane yields. In general it may be concluded that labor efficiency, measured in outputs per man, was higher for the farms with higher yields of sugar cane per cuerda.

Farm Expenses. The total expenses in hired labor were found to increase consistently with increases in the tons of sugar cane per cuerda (table 98). However, the per cent represented by hired labor expenses in sugar cane increased consistently up to the group of farms which had yields of cane ranging between 21 to 25 tons per cuerda. Beyond this point a substantial decrease was observed.

The hired labor expenses in sugar cane per cuerda of cane harvested were found to increase consistently as yield of cane per cuerda increased. When

TABLE 98. RELATION OF TONS OF SUGAR CANE PER CUERDA TO FARM EXPENSES

186 farms, Southwestern Puerto Rico, 1942–43

Tons of sugar cane per cuerda: Range	Tons of sugar cane per cuerda: Average	Number of farms	Total expenses in hired labor	Per cent hired labor expenses in cane	Hired labor expenses in cane per cuerda	Hired labor expenses in cane per ton	Fertilizer costs per cuerda of cane
			$		$	$	$
10 and less	8	24	862	48	26	3.17	4
11–15	13	47	1,208	70	33	2.45	6
16–20	17	66	2,029	71	45	2.62	8
21–25	23	29	2,444	97	56	2.41	7
26 and over	31	20	20,688	60	76	2.45	10

they were expressed in terms of per unit of production the reverse relationship was observed. That is, the hired labor expenses in sugar cane per tone of cane harvested were found to indicate a definite marked tendency of decreasing with increases in yields of cane. In other words, it costs more per cuerda to obtain higher yields of sugar cane but not per ton produced. Fertilizer expenses per cuerda of cane harvested were also found to increase with increases in sugar cane yields. These larger applications of fertilizer and of other inputs, together with better lands, more plant-cane, more mechanization, and more irrigation, were mainly responsible for the higher tonnage of sugar cane per cuerda obtained.

Farm Earnings. The higher the tonnage of sugar cane per cuerda, the higher the farm earnings of the farms studied (table 99).

The return on capital of the farms studied showed consistent increases with increases in sugar cane yields. However, when it was expressed in terms of a per cent of the total farm capital the increases did not show to

be consistent. The per cent return on capital increased with sugar cane yields up to the group of farms which ranged between 21 to 25 tons of sugar cane per cuerda. Beyond this point a substantial decrease was observed for the group of farms which had yields above 25 tons of sugar cane per cuerda. . The capital turnover tended to decrease as the yields of sugar cane increased.

Net farm cash income, labor income and labor earnings were intimately related with sugar cane yields. They showed consistent increase with increases in the tons of sugar cane produced per cuerda.

To summarize, farm earnings from the point of view of capital investment, were found to be limited by sugar cane yields up to certain extents beyond which it was uneconomical to continue increasing yields. On the other hand, from the standpoint of the operator's return there was, apparently, no limitation found within the extent of the sugar cane yields obtained by the farms studied.

TABLE 99. RELATION OF TONS OF SUGAR CANE PER CUERDA TO FARM EARNINGS

186 farms, Southwestern Puerto Rico, 1942–43

Tons of sugar cane per cuerda		Number of farms	Return on capital	Per cent return on capital	Capital turn over	Net farm cash income	Labor income	Labor earnings
Range	Average							
			$			$	$	$
10 and less	8	24	788	8.8	3.36	1,252	670	1,094
11–15	13	47	1,309	12.8	2.69	1,651	1,093	1,506
16–20	17	66	2,379	11.9	3.21	2,460	1,626	2,120
21–25	23	29	4,692	17.2	2.67	5,095	3,534	3,975
26 and over	31	20	15,922	11.8	2.87	18,725	8,632	9,198

Crop Index

A crop index was calculated to measure the yields per cuerda of crops other than sugar cane. The farms studied were grouped according to their crop index and its relationship to farm earnings and other factors was studied. The results found are presented below in tables 100 to 105.

Various Size Factors. No consistent relationship was observed between crop index (excluding sugar cane) and size of business (table 100).

It was observed, however, that the largest farms, as measured by total cuerdas in farm, net cuerdas harvested, cuerdas in sugar cane harvested, total animal units, man equivalent and total capital invested, had the lowest crop index. In general the other groups of farms studied were, on the average, of almost the same size.

Crop index, as calculated, measured only the yields of the secondary

crops in the area. As stated before, the largest farms were highly specialized in sugar cane growing and planted secondary crops mostly to qualify for the Agricultural Adjustment Administration payments. In many cases, these crops were abandoned right after government inspection. Consequently, yields were lower than those obtained by smaller farms which depended more on them as a source of direct income.

TABLE 100. RELATION OF CROP INDEX (EXCLUDING SUGAR CANE) TO VARIOUS SIZE FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Crop index (excluding sugar cane)		Number of farms	Total cuerdas in farm	Net cuerdas harvested	Cuerdas in cane harvested	Total animal units	Man equivalent	Total capital invested
Range	Average							
								$
Less than 50	27	35	498	135	113.7	88.1	22.3	83,889
50– 74	63	40	94	45	27.8	15.6	5.8	15,998
75– 99	86	50	79	40	20.8	15.0	4.4	13,754
100–124	111	33	90	44	24.2	16.4	5.5	13,524
125–149	136	31	151	47	25.6	29.5	6.3	22,261
150–174	159	22	67	39	26.5	12.0	5.0	16,836
175 and over	215	29	82	40	22.1	18.3	4.7	13,497

TABLE 101. RELATION OF CROP INDEX (EXCLUDING SUGAR CANE) TO LAND USE

240 farms, Southwestern Puerto Rico, 1942–43

Crop index (excluding sugar cane)		Number of farms	Economic land class	Per cent land arable	Per cent of arable land harvested	Per cent total area harvested net	Per cent net harvested land in cane	Per cent total harvested land in tobacco, cotton and corn
Range	Average							
Less than 50	27	35	2.9	87	31	94	84	11
50– 74	63	40	3.8	93	51	77	62	38
75– 99	86	50	4.0	84	61	84	52	36
100–124	111	33	3.7	93	53	83	55	32
125–149	136	31	3.7	91	34	84	54	35
150–174	159	22	3.8	93	62	86	68	22
175 and over	215	29	3.2	90	53	85	56	32

Land Use. In table 101 it was attempted to present the relationships between crop index (excluding sugar cane) and land use.

No consistent relationship was observed to exist between crop index and economic land class. However, the farms with the lowest crop index were found to be located in the better land classes. They cultivated the lowest percentage of the total arable land and practiced intercropping and doublecropping to the least extent. They were also found to have the

largest proportion of their net cuerdas in crops planted in sugar cane. On the contrary, they had relatively the smallest acreage in the secondary crops. The other groups of farms studied did not show much variation as to quality of the lands in which they were located and its use.

Farm expenses and Receipts. In general, no consistent relationship was observed between crop index (excluding sugar cane) and farm expenses and receipts (table 102).

The farms with the lowest crop index had the largest expenses per net cuerda harvested. They specialized more in sugar cane which requires larger expenditures per cuerda. The other farms did not show much variation between themselves. The per cent that expenses in hired labor represented of total farm cash expenses showed no relation with crop index.

TABLE 102. RELATION OF CROP INDEX (EXCLUDING SUGAR CANE) TO VARIOUS FARM EXPENSES AND RECEIPTS

240 farms, Southwestern Puerto Rico, 1942-43

Crop index (excluding sugar cane)		Number of farms	Farm cash expenses per net cuerda harvested	Per cent expenses in hired labor is of total cash expenses	Per cent income from crop sales	Per cent income from cane sales	Per cent income from tobacco, cotton and corn
Range	Average						
			$				
Less than 50	27	35	120	73	68	67	1
50- 74	63	40	64	69	67	58	9
75- 99	86	50	48	63	63	44	17
100-124	111	33	60	62	61	42	17
125-149	136	31	66	68	53	37	14
150-174	159	22	66	73	75	64	9
175 and over	215	29	59	65	62	42	15

The per cent that crop sales constituted of the farm gross receipts was not related to crop index. In fact, it did not show much variation, on the average, among the different groups of farms studied. A very clear tendency for the farms with the higher crop index to derive less of their gross income from sugar cane was observed. On the other hand, they depended to a larger extent on the income derived from tobacco, cotton and corn. A marked tendency corroborating this finding was observed.

Labor Efficiency. No relationship was found between crop index (excluding sugar cane) and labor efficiency (table 103).

When labor efficiency was measured in terms of net cuerdas harvested per man and cuerdas in sugar cane harvested per man, no relationship with crop index was found. Both the capital invested and the gross income per man showed no relationship with crop index. However, the group of farms with the lowest crop index had the highest labor efficiency, as meas-

ured by these two factors. The return on labor per man, indicated a tendency to increase with increases in the crop index. The relationship found, however, cannot be considered very significant.

Farm Earnings. Crop index (excluding sugar cane) was not found to be related to farm earnings (table 104).

TABLE 103. RELATION OF CROP INDEX (EXCLUDING SUGAR CANE) TO LABOR EFFICIENCY

240 farms, Southwestern Puerto Rico, 1942–43

Crop index (excluding sugar cane)		Number of farms	Net cuerdas harvested per man	Cuerdas in cane harvested per man	Capital invested per man	Return on labor per man	Gross income per man
Range	Average						
					$	$	$
Less than 50	27	35	6.0	5.1	3,760	732	1,201
50– 74	63	40	7.8	4.8	2,768	766	1,024
75– 99	86	50	9.3	4.8	3,159	693	978
100–124	111	33	8.0	4.4	2,458	669	925
125–149	136	31	7.5	4.1	3,554	732	1,036
150–174	159	22	7.7	5.3	3,349	761	1,064
175 and over	215	29	8.5	4.7	2,895	876	1,163

TABLE 104. RELATION OF CROP INDEX (EXCLUDING SUGAR CANE) TO FARM EARNINGS

240 farms, Southwestern Puerto Rico, 1942–43

Crop index (excluding sugar cane)		Number of farms	Capital turnover	Return on labor	Net farm cash income	Labor income	Labor earnings
Range	Average						
				$	$	$	$
Less than 50	27	35	3.13	16,340	9,571	4,012	4,518
50– 74	63	40	2.70	4,430	2,838	1,851	2,283
75– 99	86	50	3.23	3,018	2,035	1,325	1,764
100–124	111	33	2.66	3,682	2,133	1,433	1,931
125–149	136	31	3.43	4,584	3,048	1,842	2,376
150–174	159	22	3.15	3,825	2,557	1,520	1,868
175 and over	215	29	2.49	4,084	2,855	2,088	2,495

When farm earnings were measured in terms of capital turnover, no relationship with crop index was found to exist. It was only observed that the group of farms with the lowest crop index had the highest capital turnover while those with the highest crop index had the lowest.

The return on labor, net farm cash income, labor income and labor earnings of the farms studied were not found to be related to crop index. The farms with the lowest crop index, however, had consistently the highest farm earnings as measured by these four factors. For the other groups of farms they did not vary too much.

Farm Mortgage Indebtedness and Other Factors. In table 105 the relationship of crop index (excluding sugar cane) to farm mortgage indebtedness and other factors is presented.

Crop index, age of operator and farm population were not found to be related. However, the population of the farms with the lowest crop index was found to be the largest. Although no relationship was found to exist between crop index and distance of farm to nearest paved road, it was observed that the farms near the extremes in crop index were located at shorter distances.

No relationship was also found between crop index (excluding sugar cane) and the mortgage burden of the farms studied. When the total

TABLE 105. RELATION OF CROP INDEX (EXCLUDING SUGAR CANE) TO FARM MORTGAGE INDEBTEDNESS AND OTHER FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Crop index (excluding sugar cane)		Number of farms	Age of operator	Farm population	Distance to nearest paved road (kms.)	Farm mortgage indebtedness		
Range	Average					Total	Per total cuerda in farm	Per cent of total capital
						$	$	$
Less than 50.	27	35	53	53	0.6	1,629	3	2
50– 74.....	63	40	46	17	0.8	1,509	16	9
75– 99.....	86	50	50	17	1.4	1,042	13	8
100–124.....	111	33	48	22	1.0	867	10	6
125–149.....	136	31	53	22	0.9	1,702	11	8
150–174.....	159	22	48	14	0.7	930	14	6
175 and over	215	29	44	17	0.9	579	7	4

farm mortgage indebtedness was expressed per total cuerda in farm or as a per cent of the total farm capital, it was found that the farms at the extremes of the crop index had the lowest farm mortgage burden. The relationships, however, were not consistent nor significant.

Summary of Relation of Rates of Production to Farm Earnings and Other Factors

Rates of production, as measured by tons of sugar cane produced per cuerda, were found to be very influential on the farm earnings of the farms studied in Southwestern Puerto Rico. The yields of the secondary crops, as measured by crop index (excluding sugar cane) proved to be no deciding factor on the profitableness of the farms surveyed. As shown before, sugar cane accounted for nearly nine-tenths of the total crop sales of the farms under study. It was also by far the most important crop grown in the area from the point of view of acreage. This fact explains why tons

of sugar cane per cuerda were found to be of such a great influence in determining the success of the farms in Southwestern Puerto Rico. Furthermore, it also explains why the rates of production of the secondary crops bore no relationship to farm earnings.

It is attempted below to summarize the most important relationships found to exist between tons of sugar cane per cuerda, farm earnings and other factors.

1. The larger sized farms had the better yields of sugar cane per cuerda.
2. The farms located in the better land classes were found to have the higher yields of sugar cane.
3. The farms with higher yields of sugar cane had relatively larger acreages of sugar cane and harvested higher percentages of plant-cane.
4. The farms with higher sugar cane yields were found to be mechanized to a larger extent, which indicates that very probably better cultivation practices were carried on by these farms.
5. Irrigation practices were found to be carried on to larger extents by the farms with the higher yields of cane.
6. Labor efficiency, when measured in terms of output per man, was higher for the farms with higher yields of sugar cane per cuerda.
7. It cost more per cuerda to produce higher yields of sugar cane but not per ton of cane produced. That is, the value of the inputs applied per cuerda were found to be higher for the farms with higher yields of sugar cane, but resulted lower when expressed in terms of per ton of cane produced.
8. Better lands, more plant-cane harvested, better cultivation resulting from higher mechanization, more irrigation practiced and higher inputs per cuerda including heavier applications of fertilizer, were mainly responsible for the higher yields of sugar cane obtained.
9. The higher the tonnage of sugar cane per cuerda, the higher the operator's returns were found to be. From the point of view of capital investment, however, farm earnings were found to be limited by sugar cane yields up to certain extents beyond which it proved to be uneconomical to continue increasing yields.

Relation of Labor Efficiency to Farm Earnings and Other Factors

The efficiency with which labor is used in a farm is very influential in its success or failure. Labor is the most important single cost in farming. Its importance has been and will continue increasing with passing time. Cost of living, in general, as well as the standard of living of laborers has been consistently increasing. It is, therefore, very logical to expect increasing pressure on the part of laborers from higher and higher wages. Farm laborers are no exception.

This increasing importance of labor cost in farming demands corresponding increases in the output per worker in agriculture. Farms must keep pace with this increased efficiency in the use of labor. Otherwise, if they cannot go with this trend, they will be forced out of business and others will have to do the job, if they can.

Working more efficiently does not mean working longer hours. On the contrary, it means more and better work done per man, higher output units per man, higher returns per man. Labor efficiency is very tied up to size of business. The larger the size within certain economic limits, the more efficient the farm labor can be used. Of no less importance also are other factors such as good labor distribution, use of well-established machinery, use of modern methods of communication and transportation, good farm layout and buildings arrangement, good planning and timing of the work to be done, and good labor management. Farms need to watch out for these factors carefully in order to achieve higher labor efficiency and, consequently have a more successful farm business.

Labor efficiency on a farm may be measured either in terms of cuerdas and number of animals cared for per man or in terms of the quantity produced per man. Usually, the first method is used and the latter, which involves rates of production, is discarded in view of the fact that it is easier to measure rates of production separately. In the case of the farms studied in Southwestern Puerto Rico, it was preferred to measure labor efficiency in terms of gross income per man. It was considered the fact that the study was covering an entire region which included different types of farm businesses. In the absence of such good measures as productive man work units per man or output units per man, it was believed that gross income per man would serve better the purpose of comparing, on equal basis, the different farms studied in the whole region.

Farm Gross Income per Man

The relation of gross income per man, as a measure of labor efficiency, to farm earnings and other factors of farm organization and functioning is presented in tables 106 to 111 which follow.

Various Size Factors. The relation of farm gross income per man to various size factors is shown in table 106.

As the gross income per man increased, size of business, as measured by total cuerdas in farm, net cuerdas harvested, cuerdas in sugar cane harvested, total animal units and total capital invested, increased consistently up to the group of farms which had gross income per man ranging from $1200 to $1400. The farms above, which had gross income per man of $1400 and over, were found to be smaller than the previously-mentioned farms. In other words, the farms with the highest labor efficiency were

not the largest in size. As indicated before, labor efficiency is very tied up with size of business. Within certain economic limits, labor efficiency and size of business are directly associated. However, beyond those limits, it may decrease with increases in size. This is the point which individual

TABLE 106. RELATION OF FARM GROSS INCOME PER MAN TO VARIOUS SIZE FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Gross income per man: Range	Gross income per man: Average	Number of farms	Total cuerdas in farm	Net cuerdas harvested	Cuerdas in cane harvested	Total animal units	Man equivalent	Total capital invested
$	$							$
Less than 400 . . .	282	35	24	11	2.5	5.7	2.3	2,863
400– 599	516	42	27	13	5.3	7.0	2.4	4,060
600– 799	703	43	110	36	11.5	19.3	4.2	11,377
800– 999	913	41	118	52	26.9	23.2	6.4	18,412
1000–1199	1,051	25	203	82	65.0	51.7	3.7	43,832
1200–1399	1,271	22	517	175	150.4	70.1	26.4	95,127
1400 and over. . .	1,609	32	270	92	66.0	30.8	9.6	45,578

TABLE 107. RELATION OF FARM GROSS INCOME PER MAN TO LAND USE

240 farms, Southwestern Puerto Rico, 1942–43

Gross income per man: Range	Gross income per man: Average	Number of farms	Economic land class	Per cent land arable	Per cent of arable land harvested	Per cent total area harvested net	Per cent net harvested land in cane	Per cent total harvested land in tobacco, cotton and corn
$	$							
Less than 400. .	282	35	4.5	88	53	69	22	65
400– 599	516	42	4.1	89	56	82	39	50
600– 799	703	43	3.8	77	42	78	32	50
800– 999	913	41	3.2	91	49	81	52	39
1000–1199	1,051	25	3.3	84	48	86	79	18
1200–1399	1,271	22	3.3	93	36	95	86	9
1400 and over. .	1,609	32	2.7	90	38	89	72	17

farms or governmental agencies in charge of land tenure policies should watch carefully.

Land Use. Labor efficiency, as measured by gross income per man, was found to be higher for the farms which were located on better land classes (table 107). That is, the farms with the better land used labor more efficiently.

The proportion of the total farms acreage classified as arable showed no

relationship with labor efficiency. On the other side, it was found that the per cent of the total arable land which was harvested showed a tendency to decrease as the labor efficiency increased. The extent to which double-cropping and intercropping was followed on the farms had nothing to do with the efficiency in the use of labor. A very marked tendency for the farms with the larger gross income per man to have a higher percentage of the net cuerdas harvested in sugar cane, was observed. Conversely, the relative importance of tobacco, cotton and corn, form the point of view of acreage, tended to decrease with increases in labor efficiency.

TABLE 108. RELATION OF FARM GROSS INCOME PER MAN TO VARIOUS FARM EXPENSES AND RECEIPTS

240 farms, Southwestern Puerto Rico, 1942–43

Gross income per man		Number of farms	Total cash expenses per net cuerda harvested	Per cent expenses in hired labor is of total cash expenses	Per cent income from crop sales	Per cent income from cane sales	Per cent cane sales is of total crop sales	Per cent income from tobacco, cotton and corn sales
Range	Average							
$	$		$					
Less than 400..	282	35	30	60	62	21	34	41
400– 599.....	516	42	42	58	59	30	51	27
600– 799.....	703	43	44	64	61	29	47	29
800– 999.....	913	41	60	66	58	39	67	17
1000–1199.....	1,051	25	102	71	64	60	94	3
1200–1399.....	1,271	22	115	73	72	70	97	2
1400 and over..	1,609	32	71	67	60	52	87	5

Various Farm Expenses and Receipts. In table 108 it is attempted to present the relation of farm gross income per man, as a measure of labor efficiency, to various farm expenses and receipts.

In general, the inputs applied per net cuerda harvested, as measured by the total farm cash expenses, were found to be larger for the farms with a larger labor efficiency. The farms having the largest labor efficiency, however, did not apply the larger inputs per net cuerda harvested. The same group of farms which had from $1200 to $1400 in gross income per man reported, on the average, the largest amount of cash expenditures per net cuerda harvested. These farms were also found to have the largest percentage of the total farm cash expenses represented by expenses in hired labor.

The importance of crop sales as a source of income in the farms studied was found to bear no relationship at all with labor efficiency. In fact, very little variations were observed, on the average, among all groups of farms

studied. It was observed, however, that the farms which ranged between $1200 and $1400 in gross income per man had the highest per cent income from crop sales. These farms also had the largest per cent income from sugar cane sales, but the lowest per cent income from tobacco, cotton and corn sales. The per cent income from sugar cane sales showed marked tendencies to increase with increases in labor efficiency, up to that group of farms, and, thereupon showed a substantial decline. The relative importance of tobacco, cotton and corn as a source of income, on the contrary, showed tendencies of decreasing with labor efficiency increases down to the same group of farms, and then, showed an increase.

TABLE 109. RELATION OF FARM GROSS INCOME PER MAN TO VARIOUS OTHER LABOR EFFICIENCY FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Gross income per man		Number of farms	Net cuerdas harvested per man	Cuerdas in cane harvested per man	Capital invested per man	Return on labor per man
Range	Average					
$	$				$	$
Less than 400	282	35	5.0	1.1	1,264	258
400– 599	516	42	5.7	2.2	1,715	402
600– 799	703	43	8.4	2.7	2,685	490
800– 999	913	41	8.2	4.2	2,893	628
1000–1199	1,051	25	6.0	4.8	3,207	708
1200–1399	1,271	22	6.6	5.7	3,609	788
1400 and over	1,609	32	9.5	6.9	4,737	1,149

Various Other Labor Efficiency Factors. Other measures of labor efficiency were related to farm gross income per man and the results are presented in table 109.

Net cuerdas harvested per man were not consistently related with gross income per man, but the relationship found indicated a definite tendency for both to increase together. Cuerdas in sugar cane harvested per man, capital invested per man and returns on labor per man were found to be very closely associated. They all showed consistent increases as the gross income per man increased.

Farm Earnings. Labor efficiency was found to have a very direct influence on farm earnings (table 110).

The capital turnover of the farms studied showed a clear tendency to decrease with increases in labor efficiency. The farms ranging from $1200 to $1400 in gross income per man had the lowest capital turnover.

The return on labor and net farm cash income increased with increases in labor efficiency, as measured by gross income per man. Again, the farms

which reported having, on the average, gross income per man ranging from $1200 to $1400 had the largest return on labor and net farm cash income.

Both labor income and labor earnings were very closely related with labor efficiency. As the efficiency in the use of labor increased, labor income and labor earnings showed very consistent increases.

TABLE 110. RELATION OF FARM GROSS INCOME PER MAN TO FARM EARNINGS

240 farms, Southwestern Puerto Rico, 1942–43

Gross income per man		Number of farms	Capital turn-over	Return on labor	Net farm cash income	Labor income	Labor earn-ings
Range	Average						
$	$			$	$	$	$
Less than 400	282	35	4.48	583	241	−72	229
400– 599	516	42	3.32	952	519	218	517
600– 799	703	43	3.82	2,077	1,166	485	978
800– 999	913	41	3.17	3,993	2,299	1,406	1,892
1000–1199	1,051	25	3.05	9,676	5,430	3,194	3,674
1200–1399	1,271	22	2.84	20,780	11,467	5,377	6,034
1400 and over	1,609	32	2.94	11,053	8,018	6,119	6,704

TABLE 111. RELATION OF FARM GROSS INCOME PER MAN TO FARM MORTGAGE INDEBTEDNESS AND OTHER FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Gross income per man		Number of farms	Age of operator	Farm popu-lation	Distance to near-est paved road (kms.)	Farm mortagge indebtedness		
Range	Average					Total	Per total cuerda in farm	Per cent of total captal
$	$					$	$	
Less than 400	282	35	55	16	1.3	0	0	0
400– 599	516	42	53	15	1.1	234	9	6
600– 799	703	43	48	28	1.0	830	8	7
800– 999	913	41	48	18	0.9	1,367	12	7
1000–1199	1,051	25	49	23	0.6	1,082	5	2
1200–1399	1,271	22	43	39	0.8	3,278	6	3
1400 and over	1,609	32	44	33	0.7	2,730	10	6

Farm Mortgage Indebtedness and Other Factors. In table 111, farm mortgage indebtedness and other factors were related with labor efficiency, as measured by farm gross income per man.

A tendency for the age of the operator to be lower from the farms which had a higher labor efficiency was observed. Apparently, younger farmers were able to use labor more efficiently. The population of the farms with higher gross income per man were also found to be larger in size. Fur-

thermore, the farms which reported having a higher labor efficiency were located closer to paved roads.

Although the total farm mortgage indebtedness showed tendencies of being larger for the farms of higher gross income per man, no relationship was found to exist when it was expressed in terms of per total cuerdas in farm, or as a per cent of the total farm capital. Only a tendency for the farm having the extreme labor efficiency to have the lowest farm mortgage burden was observed. This same tendency has been previously noticed and explained.

Summary of Relation of Labor Efficiency to Farm Earnings and Other Factors

The following were the most important relationships found between labor efficiency, as measured by farm gross income per man, to farm earnings and other factors.

1. The higher the labor efficiency the larger the size of farm business was found to be. However, the very largest farms did not have the highest labor efficiency.
2. Labor was utilized more efficiently in the farms located in the better lands.
3. Labor efficiency bore no relationship to the amount of doublecropping and intercropping carried on in the farms studied.
4. The farms with higher percentages of the net cuerdas harvested in sugar cane had a higher labor efficiency.
5. In general, the inputs applied per net cuerda harvested were found to be larger for the farms with a larger labor efficiency. The farms with the lagest labor efficiency, however, did not apply the largest inputs per cuerda.
6. Sugar cane sales was a more important source of income for the farms with a larger labor efficiency. The importance of crop sales as a source of income was found to bear no relationship at all to labor efficiency.
7. Labor efficiency was found to have a very distinct and direct influence on farm earnings. The higher the labor efficiency the larger the farm earnings.
8. Younger farm operators were found to use labor more efficiently than the older ones.
9. The farm population was larger in the farms where labor was utilized more efficiently.
10. The farms which had higher labor efficiency were found to be located closer to paved roads.

11. No apparent relationship existed between labor efficiency and farm mortgage burden, except a tendency for the farms with the extreme efficiency in the use of labor to have the lowest mortgage burden.

Relation of Combination of Enterprises to Farm Earnings and Other Factors

The problem of selecting and combining the enterprises on a farm is chiefly the concern of the individual farmer. It is true that the general tendency in agriculture, as well as in manufacturing enterprises, is towards specialization. But nobody can tell whether a specialized or a diversified farm pays better. No general rules can be established. A combination which is best for one farm, under one set of conditions, may be entirely wrong on another farm under another set of conditions. It depends on the conditions under which the farmer is operating. The problem is one of adaptation to conditions.

In selecting the best combination of enterprises for an individual farm the first thing to be determined is the relative profits from the different enterprises best adapted to the farm. The adaptation depends primarily on their requirements of climate, soils, topography and markets. To combine the adapted enterprises into a good business, other factors have to be considered such as a good labor distribution, the best utilization of the tillable and untillable lands, the best utilization of by-products, the maintenance of farm productivity, the rotation practices to be followed, the amount of risk involved in different enterprises, the desirability of a good distribution of income during the year, the best use of buildings and machinery, the amount of capital available, and, to some extent, the type of farming of the neighbors. Personal preferences or prejudices should be considered after all others.

In general, it could be said that wherever two or more enterprises are found to be about equally profitable, a diversified farm business is most desirable. But where there is one enterprise which is far more profitable than any other, a specialized business is desirable.

In Southwestern Puerto Rico there exists an apparent specialization in sugar cane growing. In the following pages we attempt to describe the extent to which this type of specialization contributed to the success of the farms studied in the area during the crop year 1942–43. Several factors, measuring the importance of the sugar cane enterprise in the farms surveyed were related to farm earnings and other factors of organization and operation; namely, per cent area in sugar cane is of total cuerdas harvested, per cent income from sugar cane, and per cent sales of sugar cane is of total crop sales. The most important findings are presented below.

Per Cent Area in Sugar Cane Is of Total Cuerdas Harvested

The relation of per cent area in sugar cane is of total cuerdas harvested to farm earnings and other factors is presented in tables 112 to 117 which follow. They will give an idea of the influence of relatively larger sugar cane acreages on the financial success of the farmers in Southwestern Puerto Rico.

Various Size Factors. Sugar cane specialization, as measured by the proportion that the sugar cane acreage was of the total cuerdas harvested, showed tendencies to be related with size of business (table 112). Although no general consistent relationships were found, definite tendencies for size of business to increase together with the per cent area in sugar cane is of total cuerdas harvested were observed.

TABLE 112. RELATION OF PER CENT AREA IN SUGAR CANE IS OF TOTAL CUERDAS HARVESTED TO VARIOUS SIZE FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent area in sugar cane is of total cuerdas harvested: Range	Average	Number of farms	Total cuerdas in farm	Net cuerdas harvested	Cuerdas in cane harvested	Tons of cane harvested	Tons of sugar produced	Man equivalent	Total capital invested
									$
0	0	54	105	28	0.0	0	0.0	3.6	12,222
Less than 40	18	28	145	49	10.9	169	21.2	5.1	15,971
40–54	46	35	89	50	26.3	405	53.2	4.9	15,477
55–69	63	42	54	32	24.1	408	52.0	4.0	10,171
70–84	80	52	234	73	62.4	1,376	178.6	11.5	42,779
85 and over	93	29	322	127	119.6	3,509	441.2	20.1	64,183

Size of business was measured in this case by total cuerdas in farm, net cuerdas harvested, cuerdas in sugar cane harvested, tons of sugar cane harvested, tons of sugar produced, man equivalent and total capital invested. Only the tons of sugar cane harvested showed consistent increases in sugar cane acreage.

Land Use and Other factors. In general, the farms with relatively larger acreages in sugar cane had the better lands, as indicated by the economic land class (table 113). However, no relationship was observed between the per cent of the farm acreage which was arable and sugar cane specialization. No relationship was also found to exist between the per cent of the total arable land which was harvested and the relative importance of sugar cane acreage.

The farms with larger acreages of sugar cane were found to be mechanized to a larger extent than those with relatively less sugar cane, as shown by the fact that they had consistently larger investments in machinery and equipment per net cuerda harvested. When the total farm capital was

expressed in terms of per cuerda of arable land, consistent increases with increases in the relative importance of the sugar cane acreage were observed. In other words, the better lands could support economically larger investments per cuerda.

TABLE 113. RELATION OF PER CENT AREA IN SUGAR CANE IS OF TOTAL CUERDAS HARVESTED TO LAND USE AND OTHER FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent area in sugar cane is of total cuerdas harvested: Range	Average	Number of farms	Economic land class	Per cent land arable	Per cent of arable land harvested	Equipment investment per cuerda harvested	Total capital invested per cuerda of arable land
						$	$
0	0	54	4.9	90	30	9	129
Less than 40	18	28	3.7	74	46	8	150
40–54	46	35	3.4	89	63	10	197
55–69	63	42	3.8	93	64	19	203
70–84	80	52	3.1	88	35	29	208
85 and over	93	29	2.0	94	42	108	212

TABLE 114. RELATION OF PER CENT AREA IN SUGAR CANE IS OF TOTAL CUERDAS HARVESTED TO IRRIGATION

240 farms, Southwestern Puerto Rico, 1942–43

Per cent area in sugar cane is of total cuerdas harvested		Investment in irrigation equipment					Cuerdas in sugar cane irrigated		
Range	Average	Number of farms	Total	Per cuerda of cane harvested	Per cuerda of cane irrigated	Per cent of total capital	Total	Per cent of total arable land	Per cent of cane harvested
			$	$	$				
0	0	54	0	0	0	0.0	0.0	0.0	0.0
Less than 40	18	28	17	2	20	0.1	0.9	0.8	7.9
40–54	46	35	3	*	*	†	0.0	0.0	0.0
55–69	63	42	75	3	144	0.7	0.5	1.0	2.2
70–84	80	52	588	9	28	1.4	21.0	10.2	33.6
85 and over	93	29	9,396	79	126	14.6	74.3	24.5	62.1

* Less than $0.50.

† Less than 0.05 per cent.

Irrigation. In table 114, the relation of per cent area in sugar cane is of total cuerdas harvested to irrigation is presented.

Definitely it was corroborated that the farmers who had relatively harvested more sugar cane owned practically all the irrigation equipment and practiced almost all the irrigation which was carried on in the farms studied. They also irrigated larger percentages of their sugar cane land.

Rates of Production and Labor Efficiency. Rates of production, as measured by tons of sugar cane per cuerda and tons of sugar produced per cuerda,

were in general consistently higher for the farms with relatively larger acreages in sugar cane (table 115).

The degree of efficiency in the utilization of labor was found to be higher on the farms with larger percentages of their total cuerdas harvested in sugar cane. The tons of sugar cane produced per man as well as the gross income per man showed consistent increases with increases in the per cent that the area in sugar cane was of the total cuerdas harvested.

The farms with the largest net acreage harvested per man were found to be those which had between 40 to 54 per cent of their total cuerdas harvested in sugar cane. Beyond this point, consistent decreases were observed. The same thing happened in the case of cuerdas in sugar cane harvested per man. The farms which had from 55 to 69 per cent of the total crop acreage in sugar cane were the ones to report the largest number

TABLE 115. RELATION OF PER CENT AREA IN SUGAR CANE IS OF TOTAL CUERDAS HARVESTED TO RATES OF PRODUCTION AND LABOR EFFICIENCY

240 farms, Southwestern Puerto Rico, 1942–43

Per cent area in sugar cane is of total cuerdas harvested: Range	Per cent area in sugar cane is of total cuerdas harvested: Average	Number of farms	Tons of cane per cuerda	Tons of sugar per cuerda	Tons of cane per man	Net cuerdas harvested per man	Cuerdas in cane harvested per man	Capital invested per man	Gross income per man
								$	$
0	0	54	0	0.0	0	7.8	0.0	3,411	733
Less than 40	18	28	16	2.0	33	9.6	2.1	3,112	878
40–54	46	35	15	2.0	83	10.3	5.4	3,182	932
55–69	63	42	17	2.2	103	8.1	6.1	2,570	1,023
70–84	80	52	22	2.9	120	6.4	5.4	3,734	1,185
85 and over	93	29	29	3.7	175	6.3	6.0	3,199	1,253

of cuerdas in sugar cane harvested per man. Beyond this point, as in the former case, gradual declines were observed.

The capital invested per man and the relative importance of the sugar cane acreage in the farms studied showed no apparent relationship. In fact, very little variation among the different groups of farms studied was found to exist.

Various Farm Expenses and Receipts. The hired labor expenses in sugar cane tended to be relatively higher for the farms with higher percentages of their total cropland in sugar cane (table 116). These farms also tended to apply more inputs per cuerda of cane as measured by the hired labor expenses in sugar cane per cuerda of cane harvested. The hired labor expenses in sugar cane when expressed in terms of per ton of cane harvested, however, showed a definite tendency to decrease as the importance of the sugar cane acreage increased. Heavier applications of fertilizer were also made in the farms which specialized more in the sugar cane enterprise.

The farms specialized to a larger extent in sugar cane growing, as measured by the per cent that the sugar cane acreage was of the total cuerdas harvested, had, on the average, larger receipts from sugar cane per cuerda of cane harvested. They also were found to derive a larger proportion of their gross income from sugar cane.

TABLE 116. RELATION OF PER CENT AREA IN SUGAR CANE IS OF TOTAL CUERDAS HARVESTED TO VARIOUS FARM EXPENSES AND RECEIPTS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent area in sugar cane is of total cuerdas harvested: Range	Average	Number of farms	Per cent hired labor expenses in cane	Hired labor expenses in cane per cuerda	Hired labor expenses in cane per ton	Fertilizer costs per cuerda of cane	Total cane receipts per cuerda	Per cent income from cane
				$	$	$	$	$
0	0	54	0	0	0.00	0	0	0
Less than 40	18	28	39	48	3.10	6	122	29
40–54	46	35	63	36	2.33	6	117	68
55–69	63	42	76	37	2.19	7	135	80
70–84	80	52	70	56	2.55	9	167	77
85 and over	93	29	87	73	2.49	8	204	97

TABLE 117. RELATION OF PER CENT AREA IN SUGAR CANE IS OF TOTAL CUERDAS HARVESTED TO FARM EARNINGS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent area in sugar cane is of total cuerdas harvested: Range	Average	Number of farms	Return on capital	Per cent return on capital	Capital turnover	Net farm cash income	Labor income	Labor earnings
			$			$	$	$
0	0	54	892	7.3	4.65	1,131	542	968
Less than 40	18	28	1,771	11.1	3.55	2,082	1,240	1,740
40–54	46	35	1,764	11.4	3.42	2,179	1,249	1,785
55–69	63	42	1,543	15.2	2.51	1,978	1,318	1,733
70–84	80	52	5,689	13.3	3.15	5,698	3,730	4,208
85 and over	93	29	7,585	11.8	2.55	9,601	4,211	4,600

Farm Earnings. Specialization in sugar cane, as measured by per cent area in sugar cane is of total cuerdas harvested, was found to be intimately related to the financial success of the farms studied (table 117).

The return on capital was found to increase consistently with increases in the relative importance of the sugar cane acreage. However, when it was expressed as a per cent of the total farm capital, consistent increases were observed up to the group of farms which had 55 to 69 per cent of their total crop acreage in sugar cane. The per cent return on capital decreased substantially beyond this point. A marked tendency was also observed for the farms with relatively more sugar cane to have a lower capital turnover.

Sugar cane specialization, net farm cash income, labor income and labor earnings were found to be very directly associated. In general they all increased consistently together.

Per Cent Sales of Sugar Cane Is of Total Crop Sales

The relation of sales of sugar cane is of total crop sales to farm earnings and other factors is presented in table 118 to 121 which follow. This factor measures, from the standpoint of crop sales, the importance of the sugar cane enterprise as compared to other crops grown on the farms studied. It also measures, to some extent, the importance of the sugar cane enterprise, considering the farm business as a whole.

Various Size Factors. In table 118 it is attempted to present the relation of per cent sales of sugar cane is of total crop sales to various size factors.

TABLE 118. RELATION OF PER CENT SALES OF SUGAR CANE IS OF TOTAL CROP SALES TO VARIOUS SIZE FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent sales of sugar cane is of total crop sales		Number of farms	Total cuerdas in farm	Net cuerdas harvested	Cuerdas in cane harvested	Tons of cane harvested	Man equivalent	Total capital invested
Range	Average							
								$
0	0	54	105	28	0.0	0	3.6	12,222
Less than 75	46	47	134	56	22.0	284	5.8	16,151
75–94	87	52	64	38	25.1	466	4.3	12,112
95 and over	99	87	245	84	76.0	2,015	13.4	47,276

Sugar cane specialization proved to be directly related to size of farm business, as measured by cuerdas in sugar cane harvested and tons of sugar cane harvested. They both increased consistently as the per cent sales of sugar cane is of total crop sales increased. When size of business was measured by total cuerdas in farm, net cuerdas harvested, man equivalent and total capital invested, no consistent direct relationships were observed. However, very definite tendencies for these factors to increase with increases in the degree of sugar cane specialization were found to exist.

Land Use and Other Factors. Sugar cane specialization, as measured by per cent sales of sugar cane is of total crop sales, was related to land use and other factors. The relationships found are shown in table 119.

The farms more highly specialized in the sugar cane enterprise were found to be located in the better lands of the area.

The per cent land arable showed no relationship with sugar cane specialization. The same lack of relationship was observed in the case of the

per cent of the arable land which was harvested. However, both groups of farms at the extreme in sugar cane specialization reported having, on the average, the lowest percentages of their total arable land harvested. The farms in which sugar cane sales accounted for between 75 to 94 per cent of their total crop sales harvested the highest proportion of their arable lands. These same observations were noticed in the case of the per cent of the total arable land which was planted in sugar cane. The per cent that the sugar cane acreage constituted of the net cuerdas harvested was found to increase consistently as the percent of the total crop sales derived from sugar cane increased.

The total capital invested per cuerda of arable land increased with increases in sugar cane specialization. This was due, of course, to the higher value of the better lands as well as to the higher investments in machinery and equipment per cuerda which these better lands could stand.

TABLE 119. RELATION OF PER CENT SALES OF SUGAR CANE IS OF TOTAL CROP SALES TO LAND USE AND OTHER FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent sales of sugar cane is of total crop sales		Number of farms	Economic land class	Per cent land arable	Per cent of arable land harvested	Per cent of arable land in cane	Per cent net harvested land in cane	Total investments per cuerda of arable land
Range	Average							
								$
0	0	54	4.9	90	30	0	0	129
Less than 75	46	47	3.9	81	52	20	39	148
75–94	87	52	3.4	88	67	45	67	215
95 and over	99	87	2.8	91	38	34	90	213

Rates of Production and Labor Efficiency. The tons of sugar cane produced per cuerda and sugar cane specialization, was measured by per cent sales of sugar cane is of total crop sales, were found to be closely directly associated (table 120). The higher the degree of specialization, the better the yields of cane were found to be. As indicated before, these farms were located in the better lands and were found also to apply more inputs per cuerda of cane cultivated.

Labor efficiency, as measured by both tons of sugar cane produced per man and gross income per man, were found to be directly associated with the degree of specialization in the sugar cane enterprise. They all were found to increase consistently together.

Both cuerdas in sugar cane harvested per man and return on labor per man indicated a tendency to increase with increases in the per cent of the total crop sales constituted by sugar cane. Based on these two factors, the farms with the highest labor efficiency were those in which sugar cane sales

accounted for between 75 to 94 per cent of the total crop sales. Beyond this point, decreases in labor efficiency were recorded.

Net cuerdas harvested per man and capital invested per man were found to bear no relationship to sugar cane specialization.

Farm Earnings. Specialization in the sugar cane enterprise proved to be intimately related to farm earnings (table 121).

The farms with larger percentages of their crop sales accounted for by sugar cane sales had consistently larger returns on capital. When the

TABLE 120. RELATION OF PER CENT SALES OF SUGAR CANE IS OF TOTAL CROP SALES TO RATES OF PRODUCTION AND LABOR EFFICIENCY

240 farms, Southwestern Puerto Rico, 1942–43

Per cent sales of sugar cane is of total crop sales: Range	Average	Number of farms	Tons of cane per cuerda	Tons of cane per man	Net cuerdas harvested per man	Cuerdas in cane harvested per man	Capital invested per man	Return on labor per man	Gross income per man
							$	$	$
0	0	54	0	0	7.8	0.0	3,411	477	733
Less than 75	46	47	13	49	9.7	3.8	2,789	626	865
75–94	87	52	19	111	8.8	5.9	2,829	810	1,097
95 and over	99	87	26	147	6.3	5.7	3,537	794	1,213

TABLE 121. RELATION OF PER CENT SALES OF SUGAR CANE IS OF TOTAL CROP SALES TO FARM EARNINGS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent sales of sugar is of total crop sales: Range	Average	Number of farms	Return on capital	Per cent return on capital	Capital turnover	Return on labor	Labor income	Labor earnings
			$			$	$	$
0	0	54	892	7.3	4.65	1,717	542	968
Less than 75	46	47	1,809	11.2	3.22	3,631	1,343	1,880
75–94	87	52	1,914	15.8	2.58	3,483	1,564	2,026
95 and over	99	87	5,815	12.3	2.92	10,640	3,511	3,936

return on capital was expressed as a per cent of the total farm capital, consistent increases were found to occur as sugar cane specialization increased, up to the farms which derived between 75 to 94 per cent of their total crop sales from sugar cane. A substantial decrease beyond this point was recorded. A very definite tendency for the gross receipts of the farms less specialized in sugar cane to take more years to equalize the total farm capital was observed.

Sugar cane specialization was found to be closely associated with the return on labor, labor income and labor earnings of the farms studied in Southwestern Puerto Rico. In other words, the more the farms studied

specialized in the sugar cane enterprise the higher the farm earnings were found to be. This finding is corroborated here once more.

Per Cent Income from Sugar Cane

The relation of degree of sugar cane specialization, as measured by per cent income from sugar cane, to farm earnings and other factors is shown in tables 122 to 127 presented below. This factor measures sugar cane specialization from the income viewpoint, and, therefore takes into consideration the farm business as a whole.

Various Size Factors. The relation of per cent income from sugar cane to size of business is presented in table 122.

Although no definite consistent relationship was observed between per cent income from sugar cane and size of business, there was a tendency for

TABLE 122. RELATION OF PER CENT INCOME FROM SUGAR CANE TO VARIOUS SIZE FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent income from sugar cane: Range	Average	Number of farms	Total cuerdas in farm	Net cuerdas harvested	Cuerdas in cane harvested	Tons of cane harvested	Tons of sugar produced	Man equivalent	Total capital invested
									$
0	0	54	105	28	0.0	0	0.0	3.6	12,222
Less than 45	21	25	149	48	9.1	125	15.2	5.2	15,520
45–59	52	23	322	75	48.5	745	98.6	9.7	43,665
60–74	66	36	56	29	20.2	322	39.9	4.1	10,247
75–89	82	45	125	56	42.7	924	120.4	8.2	27,476
90 and over	97	57	213	96	86.9	2,385	302.1	13.8	43,935

the larger farms to derive more of their gross income from sugar cane. Curiously enough, the farms which derived from 45 to 59 per cent of their gross income from cane had a larger farm acreage than, and about the same total capital invested as, the farms which made nine-tenths or more of their gross receipts from sugar cane. These farms were mostly owned by people who have some of their lands at the valley planted in sugar cane and still larger acreages in pasture located in the surrounding hills or in the dry coastal area. The hilly and coastal lands are utilized principally in livestock farming, mainly dairying. On the other side, the farms which derived from 60 to 74 per cent of their gross income from sugar cane had the smallest total acreage and the smallest total capital investment. These ones are mainly the property of farmers who only own smaller acreages in the valley proper and utilized them mostly in sugar cane growing. This partly explains the apparent inconsistency observed between size of business and per cent income from sugar cane.

Land Use and Other Factors. In table 123 the relationships found to exist between sugar cane specialization and land use and other factors are presented.

The farmers more specialized in the sugar cane business had better lands than those with a less degree of specialization. That is, they were located in better land classes than the other farms.

The per cent of the total farm acreage which was arable showed no relationship with per cent income from sugar cane. However, a tendency for the farms more specialized in sugar cane to have higher percentages of their total arable land harvested was observed. The per cent of the net area harvested which was in sugar cane was found to increase consistently with increases in sugar cane specialization, as measured by per cent income from sugar cane.

TABLE 123. RELATION OF PER CENT INCOME FROM SUGAR CANE TO LAND USE AND OTHER FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent income from sugar cane: Range	Per cent income from sugar cane: Average	Number of farms	Economic land class	Per cent land arable	Per cent of arable land harvested	Per cent net harvested land in cane	Equipment investment per cuerda harvested	Total investments per cuerda of arable land
							$	$
0	0	54	4.9	90	30	0	9	129
Less than 45	21	25	3.8	72	44	19	9	144
45–59	52	23	3.7	91	26	64	20	149
60–74	66	36	3.8	91	58	69	14	202
75–89	82	45	3.2	82	55	76	32	269
90 and over	97	57	2.5	95	47	91	78	218

The farms more highly specialized in sugar cane growing were mechanized to a larger extent than those where sugar cane was of relatively less importance from the viewpoint of income. Sugar cane growing naturally requires larger investments in machinery and equipment. The machinery and equipment is not only larger in quantity but is of a more expensive nature, especially if it is for irrigation purposes. Logically, the total capital invested per cuerda of arable land was found to be higher for the farms which specialized more in the sugar cane enterprise. As indicated before, both the higher value of the better lands and the larger investments in machinery and equipment were mainly responsible for this relationship.

Irrigation. It is attempted in table 124 to indicate the fact that the farms studied in Southwestern Puerto Rico which were specialized in sugar cane to a higher extent had larger investments in irrigation equipment. They consequently practiced irrigation to considerably larger extents than those where the sugar cane enterprise was of less importance.

Rates of Production and Labor Efficiency. Rates of production, as measured by tons of sugar cane, and tons of sugar, produced per cuerda, were intimately related to the degree of sugar cane specialization in the farms studied (table 125). They were found to increase consistently with increases in the per cent income from sugar cane. As previously shown,

TABLE 124. RELATION OF PER CENT INCOME FROM SUGAR CANE TO IRRIGATION

240 farms, Southwestern Puerto Rico, 1942–43

Per cent income from sugar cane		Number of farms	Investment in irrigation equipment				Cuerdas in sugar cane irrigated		
Range	Average		Total	Per cuerda cane harvested	Per cuerda of cane irrigated	Per cent of total capital	Total	Per cent of total arable land	Per cent of cane harvested
			$	$	$				
0	0	54	0	0	0	0.0	0.0	0.0	0.0
Less than 45	21	25	19	2	20	0.1	1.0	0.9	10.5
45–59	52	23	168	4	13	0.4	13.1	4.5	27.0
60–74	66	36	0	0	0	0.0	0.0	0.0	0.0
75–89	82	45	491	12	52	1.8	9.4	9.2	22.1
90 and over	97	57	4,919	57	110	11.2	44.6	22.1	51.3

TABLE 125. RELATION OF PER CENT INCOME FROM SUGAR CANE TO RATES OF PRODUCTION AND LABOR EFFICIENCY

240 farms, Southwestern Puerto Rico, 1942–43

Per cent income from sugar cane		Number of farms	Tons of cane per cuerda	Tons of sugar per cuerda	Tons of cane per man	Net cuerdas harvested per man	Cuerdas in cane harvested per man	Capital invested per man	Gross income per man
Range	Average								
								$	$
0	0	54	0	0.0	0	7.8	0.0	3,411	733
Less than 45	21	25	14	1.7	24	9.2	1.8	2,982	844
45–59	52	23	15	2.0	77	7.7	5.0	4,487	1,153
60–74	66	36	16	2.0	78	7.1	4.9	2,484	897
75–89	82	45	22	2.8	112	6.8	5.2	3,342	1,041
90 and over	97	57	27	3.5	173	6.9	6.3	3,189	1,278

better lands, irrigation and higher inputs applied per cuerda explain these higher yields.

Labor efficiency is always very much related to size of business. As indicated above, no consistent relationship was found to exist between size of business and per cent income from sugar cane. Consequently, no general consistent relationship was observed between per cent income from sugar cane and labor efficiency as measured by various factors. For instance, cuerdas in sugar cane harvested per man and tons of sugar cane produced

per man increased consistently with increases in sugar cane specialization. On the other side, when labor efficiency was measured in terms of gross income per man, only a slight tendency to increase as the degree of sugar cane specialization increased was recorded. No relationship at all was observed between both net cuerdas harvested per man, and capital invested per man with per cent income from sugar cane.

Various Farm Expenses and Receipts. The farms which derived higher percentages of their gross receipts from sugar cane, that is, those which specialized more in sugar cane production, applied more inputs per cuerda of cane harvested (table 126).

Hired labor expenditures in sugar cane per cuerda of cane harvested increased with increases in the percent income from sugar cane. However,

TABLE 126. RELATION OF PER CENT INCOME FROM SUGAR CANE TO VARIOUS FARM EXPENSES AND RECEIPTS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent income from sugar cane		Number of farms	Per cent hired labor expenses in cane	Hired labor expenses in cane per cuerda	Hired labor expenses in cane per ton	Fertilizer costs per cuerda of cane	Total cane receipts per cuerda
Range	Average						
				$	$	$	$
0	0	54	0	0	0.00	0	0
Less than 45	21	25	35	51	3.75	5	100
45–59	52	23	59	44	2.87	7	121
60–74	66	36	67	40	2.53	8	122
75–89	82	45	68	52	2.42	9	164
90 and over	97	57	79	67	2.43	8	196

they were found to decrease nearly consistently when expressed in terms of per ton of cane harvested. The sugar cane enterprise consumed larger proportions of the total hired labor expenses in the farms specialized to a higher extent in sugar cane production. They were also found to make heavier applications of fertilizer per cuerda of cane harvested. Higher yields per cuerda accounted for consistently larger total receipts from sugar cane per cuerda of cane harvested.

Farm Earnings. Per cent income from sugar cane and farm earnings were not found to be so closely associated. Only tendencies for the farms with higher percentages of their gross income derived from sugar cane to have larger farm earnings were observed (table 127).

The return on capital, net farm cash income, labor income and labor earnings of the farms which derived from 45 to 59 per cent of their gross receipts from sugar cane were second to those obtained by the farms where sugar cane accounted for 90 per cent or more of their total gross income. It was explained before that considerable portions of the lands of these

farms were located on the surrounding hills and coast line, and that they were mostly used in pasture for livestock raising and dairying. This fact suggests the advisability of considering livestock raising and dairying as a profitable enterprise adapted to the hilly and coast lands not irrigable surrounding the valley.

The return on capital, when expressed as a per cent of the total capital investment showed definitely a tendency to increase as the degree of specialization in sugar cane was higher. It was also found that the farms more highly specialized in sugar cane tended to have lower capital turnover than those where sugar cane was less important. Therefore, from the capital investment standpoint, the higher the degree of specialization in sugar cane, the better the financial success of the farms studied in Southwestern Puerto Rico.

TABLE 127. RELATION OF PER CENT INCOME FROM SUGAR CANE TO FARM EARNINGS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent income from sugar cane		Number of farms	Return on capital	Per cent return on capital	Capital turn-over	Net farm cash income	Labor income	Labor earnings
Range	Average		$			$	$	$
0	0	54	892	7.2	4.65	1,131	542	968
Less than 45	21	25	1,654	10.7	3.53	1,955	1,148	1,643
45–59	52	23	5,100	11.7	3.89	4,905	3,195	3,932
60–74	66	36	1,151	11.2	2.77	1,433	921	1,344
75–89	82	45	3,121	11.4	3.21	3,448	1,954	2,423
90 and over	97	57	6,165	14.0	2.50	7,436	3,976	4,338

Summary of Relation of Combination of Enterprise to Farm Earnings and Other Factors

Sugar cane was by far the most important and profitable enterprise in the farms studied in Southwestern Puerto Rico during the crop year 1942-43. Several factors which attempt to measure the degree to which the farms surveyed specialized in this enterprise were related above to farm earnings and other factors of farm organization and operation. The most important findings observed are summarized below.

The farms which specialized to a larger extent in the sugar cane business:

1. Tended to be larger in size.
2. Were found to be located in better land classes.
3. Were mechanized to a larger extent.
4. Had larger investments per cuerda of arable land.
5. Had larger investments in irrigation equipment and carried irrigation practices to larger extents.

6. Were found to have higher yields of sugar cane per cuerda.
7. Utilized labor more efficiently.
8. Tended to apply more inputs per cuerda of sugar cane including such items as labor and fertilizer.
9. Were found to have larger returns both from the standpoint of capital investment and of returns to operators.

It was stated previously that no general rules can be established as to the best combination of enterprises. The only assertion made was that wherever two or more enterprises are found to be about equally profitable, a diversified farm business is most desirable, but where there is one enterprise which is far more profitable than any other, a specialized farm business is desirable. There is no doubt that sugar cane was the most profitable enterprise in the farms studied in the Lajas Valley proper during the crop year 1942–43. Therefore, its intensification is highly commendable. It was also found that livestock raising, mainly dairy farming, was apparently the enterprise most profitably adapted to the hilly and coast lands not irrigable surrounding the valley.

Relation of Farm Mechanization to Farm Earnings and Other Factors

The extent to which farms are mechanized may be very influential on farm returns. Mechanization is very important from both standpoints of saving human labor and doing a better work. However, low investments in machinery and equipment do not mean higher efficiency in the use of same and vice-versa. The main objective of mechanizing is to do better work in the least period of time and with a minimum of human labor, which is becoming more and more expensive every day.

To achieve higher efficiency in the use of machinery and equipment and to reduce its cost, several factors must be taken into consideration. Only the necessary equipment should be bought and, if possible buy second-hand equipment if the amount of use is small. In this way depreciation and interest costs would not be so high. The equipment purchased should also be properly cared for. This does not mean that it should not be used much. On the contrary, the more a machine is used, the less the fixed expenses, such as depreciation and interest are. Farmers themselves should be very careful in watching out for these points.

Per Cent Investment in Machinery and Equipment Is of Total Capital Invested

In Southwestern Puerto Rico, the degree of farm mechanization among the farms studied showed significant variations. Therefore, it is attempted to show in tables 128 to 133, which follow, its relation to the financial success of the farm businesses studied and to other factors. The per cent

that the total investments in machinery and equipment constituted of the total farm capital was used as an indication of the extent of farm mechanization.

Various Size Factors. As was logically expected, the size of business was found to be intimately related to farm mechanization (table 128).

TABLE 128. RELATION OF PER CENT INVESTMENT IN MACHINERY AND EQUIPMENT IS OF TOTAL CAPITAL INVESTED TO VARIOUS SIZE FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent investment in machinery and equipment is of total capital invested: Range	Average	Number of farms	Total cuerdas in farm	Net cuerdas harvested	Cuerdas in cane harvested	Tons of cane harvested	Tons of sugar produced	Man equivalent	Total capital invested
									$
Less than 1...	0.2	56	31	20	15.4	308	40.1	2.9	6,039
1–2............	1.9	87	156	47	19.0	333	43.2	5.4	18,769
3–4............	3.7	45	160	60	42.8	904	115.6	8.1	29,404
5 and over....	17.3	52	271	107	86.8	2,356	298.4	16.3	55,146

TABLE 129. RELATION OF PER CENT INVESTMENT IN MACHINERY AND EQUIPMENT IS OF TOTAL CAPITAL INVESTED TO LAND USE AND OTHER FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent investment in machinery and equipment is of total capital invested: Range	Average	Number of farms	Economic land class	Per cent land arable	Per cent of arable land harvested	Per cent of arable land in cane	Equipment investment per cuerda harvested
							$
Less than 1........	0.2	56	4.3	94	70	52	*
1–2................	1.9	87	3.9	85	35	14	7
3–4................	3.7	45	4.0	90	41	30	18
5 and over.........	17.3	52	3.2	91	43	35	89

* Less than $0.50.

Size of business, as measured by total cuerdas in farm, net cuerdas harvested, cuerdas in sugar cane harvested, tons of sugar cane harvested, tons of sugar produced, man equivalent and total capital invested, increased consistently as the per cent of the total farm capital which was made by machinery and equipment increased.

Land Use and Other Factors. In table 129, the relation of per cent investment in machinery and equipment is of total capital invested to land use and other factors is presented.

The relationships found were not very definite. For instance, only tendencies for the farms with relatively larger investments in machinery

and equipment of having better lands, as measured by economic land class, were observed. No relationship was observed in the case of the per cent of the total farm acreage which was arable. The per cent that the net area harvested, as well as the area in cane harvested, constituted of the total arable land showed tendencies to be lower for the farms mechanized to a higher extent. The investment in machinery and equipment per net cuerda harvested was found to be definitely larger for the farms with higher percentages of their capital invested accounted for by machinery and equipment.

Irrigation. It was found that the farms where relatively larger investments in machinery and equipment were made has also more of the investments in irrigation equipment and, consequently, carried on irrigation practices to a larger extent (table 130).

TABLE 130. RELATION OF PER CENT INVESTMENT IN MACHINERY AND EQUIPMENT IS OF TOTAL CAPITAL INVESTED TO IRRIGATION

240 farms, Southwestern Puerto Rico, 1942–43

Per cent investment in machinery and equipment is of total capital invested		Number of farms	Investment in irrigation equipment				Cuerdas in sugar cane irrigated		
Range	Average		Total	Per cuerda of cane harvested	Per cuerda of cane irrigated	Per cent of total capital	Total	Per cent of total arable land	Per cent of cane harvested
			$	$	$				
Less than 1	0.2	56	0	0	0	0.0	0.0	0.0	0.0
1–2	1.9	87	24	1	7	0.1	3.4	2.6	17.9
3–4	3.7	45	140	3	14	0.5	10.1	7.0	23.5
5 and over	17.3	52	5,740	66	117	10.4	48.9	19.8	56.3

Rates of Production and Labor Efficiency: Sugar cane yields, as measured by tons of sugar cane and of sugar produced per cuerda, indicated a clear tendency to be larger as the per cent that the investments in machinery and equipment constituted of the total capital invested increased (table 131). Besides other factors such as better lands and irrigation, higher mechanization may have also contributed in some respects to the higher yields obtained insofar as the farm jobs may have been performed better, especially those relative to the preparation of the soils.

The per cent sucrose content of cane was found to decrease consistently with increases in farm mechanization. Very probably the fact that the farms less mechanized were located in higher lands and that they practiced very little or no irrigation, may have been causal factors to the higher sucrose content of the cane harvested.

Labor efficiency, as measured by tons of sugar cane per man and gross income per man showed marked tendencies of increasing with increases in

farm mechanization. However, farm mechanization was not found to be related to net cuerdas harvested per man, cuerdas in sugar cane harvested per man nor capital invested per man.

Various Farm Expenses and Receipts. In table 132, the relation of farm mechanization, as measured by per cent investment in machinery and equipment is of total capital invested, to various farm expenses and receipts is presented.

TABLE 131. RELATION OF PER CENT INVESTMENT IN MACHINERY AND EQUIPMENT IS OF TOTAL CAPITAL INVESTED TO RATES OF PRODUCTION AND LABOR EFFICIENCY

240 farms, Southwestern Puerto Rico, 1942–43

Per cent investment in machinery and equipment is of total capital invested		Number of farms	Tons of cane per cuerda	Tons of sugar per cuerda	Per cent sucrose content of cane	Tons of cane per men	Net cuerdas harvested per man	Cuerdas in cane harvested per man	Capital invested per man	Gross income per man
Range	Average									
									$	$
Less than 1....	0.2	56	20	2.6	13.01	105	7.0	5.2	2,061	991
1–2..........	1.9	87	18	2.3	12.98	61	8.6	3.5	3,454	981
3–4........	3.7	45	21	2.7	12.79	111	7.3	5.3	3,615	1,147
5 and over..	17.3	52	27	3.4	12.67	144	6.6	5.3	3,380	1,162

TABLE 132. RELATION OF PER CENT INVESTMENT IN MACHINERY AND EQUIPMENT IS OF TOTAL CAPITAL INVESTED TO VARIOUS FARM EXPENSES AND RECEIPTS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent investment in machinery and equipment is of total capital invested		Number of farms	Per cent hired labor expenses in cane	Hired labor expenses in cane per cuerda	Hired labor expenses in cane per ton	Fertilizer costs per cuerda of cane	Total cane receipts per cuerda
Range	Average						
				$	$	$	$
Less than 1......	0.2	56	77	44	2.20	7	163
1–2........	1.9	87	52	44	2.53	6	138
3–4........	3.7	45	67	50	2.34	8	159
5 and over..	17.3	52	73	70	2.56	9	190

The farms with larger investments in machinery and equipment showed no relationship with the proportion of the total hired labor used in the sugar cane enterprise. The hired labor expenses in sugar cane per cuerda of cane harvested were found to increase with increases in the degree of farm mechanization. However, when hired labor expenses in sugar cane were expressed in terms of per ton of cane harvested insignificant variations were observed. The farms more highly mechanized also spent more in fertilizer per cuerda of cane harvested. In spite of the larger inputs per cuerda of

cane, the receipts from sugar cane per cuerda of cane harvested were found in general to be larger for the farms with larger relative investments in machinery and equipment.

Farm Earnings. Farm mechanization and earnings were found to be very closely associated (table 133).

The return on capital increased consistently with increases in the per cent the investments in machinery and equipment constituted of the total farm capital. However, the per cent return on capital tended to be smaller for the farms mechanized to a higher extent. These farms tend to have also higher capital turnover. In other words, from the standpoint of capital investment, the farms less mechanized were apparently more efficient.

TABLE 133. RELATION OF PER CENT INVESTMENT IN MACHINERY AND EQUIPMENT IS OF TOTAL CAPITAL INVESTED TO FARM EARNINGS

240 farms, Southwestern Puerto Rico, 1942–43

Per cent investment in machinery and equipment is of total capital invested		Number of farms	Return on capital	Per cent return on capital	Capital turnover	Net farm cash income	Labor income	Labor earnings
Range	Average							
			$			$	$	$
Less than 1.....	0.2	56	1130	18.7	2.08	1366	1002	1218
1–2............	1.9	87	2257	12.0	3.52	2429	1574	2066
3–4............	3.7	45	4147	14.1	3.15	4613	2956	3506
5 and over......	17.3	52	5652	10.2	2.91	6885	2943	3516

On the contrary, the farms more mechanized had consistently larger net farm cash income, labor income, and labor earnings.

Summary of Relation of Farm Mechanization to Farm Earnings and Other Factors

To summarize, the farms mechanized to a larger extent:

1. Were found to be larger in size.
2. Tended to be located in better land classes.
3. Had larger investments in irrigation equipment and, consequently, practiced irrigation to larger extents.
4. Were found to obtain better cane yields but had lower sucrose contents.
5. Tended to use labor more efficiently.
6. Applied more inputs per cuerda of cane and had larger receipts per cuerda of cane harvested.
7. Were found to be financially more successful.

Relation of Other Miscellaneous Factors to Farm Earnings and Other Factors

Land Tenure

The relation of type of land tenure to farm earnings and other factors is presented in table 134. Size of business was measured by total capital invested, intensity of land use by economic land class, rates of production by tons of sugar cane per cuerda, labor efficiency by gross income per man, sugar cane specialization by per cent income from sugar cane and farm earnings by labor income. The farms studied were then ranked according to these factors in each different type of land tenure.

The farms operated by managers ranked first in size of business, in intensity of land use, in rates of production, in labor efficiency, in the extent of sugar cane specialization and in farm earnings. The rented farms were next in farm earnings, in rates of production, in labor efficiency and in sugar cane specialization. However, they ranked third in size of business and fourth in intensity of land use.

TABLE 134. RELATION OF TYPE OF LAND TENURE TO FARM EARNINGS AND OTHER FACTORS

240 farms, Southwestern Puerto Rico, 1942–43

Type of land tenure	Number of farms	Size of business	Intensity of land use	Rates of production	Labor efficiency	Sugar cane specialization	Farm earnings
				Ranking			
Managed	146	1	1	1	1	1	1
Rented	41	3	4	2	2	2	2
Owned and Rented	16	2	3	4	3	5	3
Owned and Managed	12	5	2	5	4	3	4
Owned	25	4	5	3	5	4	5

The group of farms which were partly owned and partly rented made third in farm earnings. They also ranked third in intensity of land use and in labor efficiency. They were found, however, to be the second largest businesses but the fourth in rates of production.

The farm businesses partly owned and partly managed came next, ranking fourth as to farm earnings. These farms were second in intensity of land use, third in sugar cane specialization, and fourth in labor efficiency. They were also found to be the smallest sized businesses studied.

The farms with the lowest farm earnings, on the average, were those completely operated by owners. They ranked third as to rates of production but were fourth in size of business and in sugar cane specialization. Furthermore, these farms were located in the poorest lands and utilized labor less efficiently than any of the other groups of farms.

To conclude, the most successful farms in the area studied were those completely operated under management, followed by those which were fully rented. The farms operated by owners who were also renting part of the land ranked third followed by those farms which were operated by owners who also were managing part of the business. The most unsuccessful farms were found to be those completely operated by their owners. Besides the economic reasons pointed out above, which obviously contributed to the lowest farm earnings, it is very probable that the higher sense of security which is naturally tied up to full ownership may also be partly responsible for the lowest intensity in the use of the land the lowest efficiency in the use of labor which characterized these farms. In other words, psychological reasons may have indirectly influenced farm earnings.

It is of great interest to observe that of the factors studied only labor efficiency ranked in the same order as farm earnings when related with type of land tenure. There is no doubt of the paramount importance of this factor relative to its influence on the financial success in farming.

Distance to Nearest Paved Road

The farms surveyed were classified as to their distances from the nearest paved roads, and its relation to farm earnings and other factors was studied.

No relationship was found to exist between distance to the nearest paved road and farm earnings. Furthermore, it showed no relation to economic land class, size of business, sugar cane specialization, inputs applied per cuerda, rates of production, nor to labor efficiency.

The only observation worth mentioning is the fact that the farms located at the very side of, or crossed by, a paved road were found to be the largest in size, to fall in the best land classes, to be specialized in sugar cane to the largest extent, to apply the most inputs per acre, to obtain the highest rates of production, to utilize labor most efficiently and, consequently, to have the largest farm earnings. So the most efficient and successful farm businesses were located on paved roads.

Age of Operator

The age of the operator is usually associated with farm earnings and other factors. Curiously enough, in the case of the farms studied in Southwestern Puerto Rico, no relationships were observed. The only observation that could be made was that the smallest sized farms were found to be those operated by individuals ranging between 41 to 50 years of age. The largest ones were operated by individuals 61 years old and over. They were also found to be the most successful farmers. This corroborates once more the fact that the largest farms had the highest returns and vice versa.

Comparative Analysis of Sugar Cane Farms with and without Irrigation

It is attempted in table 135 to present a comparative analysis of the organization and financial returns of the sugar cane farms with and without irrigation which were studied in the Lajas Valley during the year 1942–43.

Of the 186 sugar cane farms studied, in only 14 were irrigation practices carried on. These farms are larger in size as may be observed by the total cuerdas in the farm, which was 18 times greater, by the total capital invested, which was 21 times above, and by the man equivalent which surpassed 14 times that reported by the other sugar cane farms. For instance, the sugar cane farms with irrigation had an average total farm area of 1302 cuerdas as compared to 74 cuerdas for the others. Their capital invested amounted to $245,860 in comparison to $11,976 which was that of the farm with no irrigation. As to the number of men employed, the farms with irrigation reported an average total of 63.4 while the others reported only an average of 4.5 men.

These large farms had not only a large acreage but also a somewhat higher percentage of arable land, out of which they cultivated 34 per cent as compared to 55 per cent which was cultivated by the sugar cane farms with no irrigation. The per cent of the total acreage which was fitted for irrigation is only 6 per cent larger for the farms which practiced irrigation. They reported 61 and 55 per cent each. These farms also were found to be specialized to a higher degree in sugar cane production, as shown by the fact that the average total of 333 cuerdas in sugar cane represented 88 per cent of the net area in crops. In the case of the farms with no irrigation an average of 25 cuerdas in sugar cane were reported per farm making only 72 per cent of the net crop acreage. Furthermore, the per cent income from sugar cane, as shown in the same table is 10 per cent higher for these farms. The farmers who irrigated, performed this practice in only 72 per cent of their sugar cane area. For one or the other reason, they were unable to irrigate all the sugar cane planted.

Although the average land value per cuerda was practically the same for both groups of farms, the total capital investment per cuerda was found to be larger for the farms with irrigation. This is accounted for by the higher degree of mechanization of these farms as shown by the fact that the total investment in machinery and equipment per net cuerda cultivated averaged $89 for them as compared to an average of $13 for the other group. The investment in irrigation equipment, which is a very expensive proposition, could only be afforded by them, and this item alone accounted for $92 per cuerda of cane irrigated.

TABLE 135. COMPARATIVE ANALYSIS OF SUGAR CANE FARMS WITH AND WITHOUT IRRIGATION

186 farms, Southwestern Puerto Rico, 1942–43

Item	Farms with irrigation	Farms with no irrigation
	Average per farm	
Number of farms	14	172
Total area in farms, cuerdas	1,302	74
Per cent arable	90	86
Per cent fitted for irrigation	61	55
Per cent arable land cultivated	34	55
Cuerdas in sugar cane	333	25
Per cent of net area in crops	88	72
Per cent irrigated	71	0
Capital invested	$245,860	$11,976
Per cuerda in farm	$189	$162
Value of land per cuerda	$137	$132
Investment in machinery and equipment per net cuerda cultivated	$89	$13
Investment in irrigation equipment	$21,683	$0
Per cuerda of cane irrigated	$92	$0
Man equivalent	63.4	4.5
Per cent hired	98	73
Yield of cane per cuerda, tons	28.9	17.4
Yield of sugar per cuerda, tons	3.67	2.24
Income from cane per cuerda of cane harvested	$158	$95
Total income from cane (including A.A.A. payments) per cuerda of cane harvested	$202	$137
Total farm gross receipts per net cuerda cultivated	$203	$131
Per cent income from cane	85	75
Farm cash expenses per net cuerda cultivated	$117	$66
Hired day-labor in sugar cane per cuerda of cane harvested	$74	$41
Total cost of hired labor per net cuerda cultivated	$88	$40
Total cost of hired labor per hired man	$550	$418
Farm income	$30,149	$2,081
Per net cuerda cultivated	$77	$60
Capital turnover	3.1	2.6
Return on capital	$28,402	$1,711
Per cent return on capital	11.6	14.3
Return on labor	$50,616	$3,286
Return on labor per man	$799	$733
Labor income	$15,397	$1,362
Per net cuerda cultivated	$39	$39

As indicated above, the number of men hired during the year by the group of farms with irrigation was larger than that reported by the other

group of sugar cane farms. But what is still more interesting is the fact that the sugar cane farms with irrigation, on the average, hired 98 per cent of the total number of men employed during the year, while the other group hired only an average of 73 per cent. This shows definitely the higher degree of commercialization of these farms.

The yields of sugar cane, expressed both in tons of sugar cane and in sugar production per cuerda, was far higher for the group of farms which practiced irrigation. It is shown in table 135 that this group of farms produced 28.9 tons of sugar cane or 3.67 tons of sugar per cuerda while the farms with no irrigation produced only 17.4 tons of sugar cane or 2.24 tons of sugar to the acre. These higher yields can be mostly attributed to the irrigation practice followed, since, as stated above, the quality of the land, as measured by its value per cuerda, was practically the same. It is true, however, that because of the fact that they are more mechanized they can perform better jobs; but it should be remembered that the mechanization of these farms is mostly accounted for by the investment in irrigation equipment. It may be argued also that, as shown in table 135, these farms put more labor per cuerda of cane harvested. However, we should not forget that the practice of irrigating sugar cane is an expensive high-labor-consuming practice which very probably accounts for most of the difference found. As to the quality of the labor itself, it is true that the table shows an apparent higher quality for these farms as indicated by the total cost of hired labor per man. However, the difference is not so great and furthermore it is convenient to point out here again that practically all of the labor employed by these farms was hired and of a more specialized nature. Hired labor is more expensive, on the average, than family labor, which is generally evaluated at a lower level.

Higher yields brought consequently higher receipts which were large enough to offset the larger expenditures in which the farms which practiced irrigation incurred. With a larger sized business and $17 more of farm income per net cuerda cultivated, the farm income for the farms where irrigation was practiced was consequently larger. This accounted for a larger total return on capital, return on labor and labor income for this group of farms. This labor income averaged $15,397 per farm as compared to $1,362 for the farms with no irrigation. However, it takes more years on these farms than on the others for the total receipts to equalize the capital invested as shown by a capital turnover of 3.1 and 2.6 respectively. The per cent return on capital was also lower for the farms irrigating, that is, 11.6 as compared to 14.3 for the others. Furthermore, when the labor income is calculated (which puts the farms on a comparable basis regardless of capital) and express it in terms of net cuerdas cultivated, amazingly enough, it was found that the labor income per net cuerda cultivated was $39 for

both groups of farms. From the point of view of capital investment irrigation is not such a good paying proposition on the part of the farmers who contributed the capital. This suggests, furthermore, that such large investments which undoubtedly increase substantially the farm income, had to be financed by outsiders, in our case, the Government.

From the social point of view, as indicated by the larger average return on labor which the farms with irrigation reported having, and a return on labor per man of $66 above the other group, the practice of irrigating land in the area brings an average yearly higher income per man employed in the farm business, and may consequently bring higher levels of living to them and their families.

Summary of Factors Affecting Farm Earnings

One of the main objectives of the farm management study undertaken in the Southwestern part of the Island was to determine the reasons for variations in farm returns, that is, why some farmers paid more than the others. In this section the relation of size of business, intensity of land use, rates of production, labor efficiency, combination of enterprises, farm mechanization and of other miscellaneous factors, to farm earnings and other factors of farm operation and functioning were presented. Several measures for each one of the above-mentioned factors were selected and the most important relationships observed were summarized. In spite of this fact, a brief, final, general summary of the most important relevant findings may prove very valuable. The paragraphs below will serve this purpose.

Size of business, intensity of land use, rates of production, labor efficiency, combination of enterprises and farm mechanization were found to be very influential to the success of the farms surveyed in Southwestern Puerto Rico. No one can tell which was the most important. As indicated before, those farms which were able to combine these factors to the best advantages were undoubtedly the most profitable.

The most successful farmers were found to be those who:

1. Had the largest size business.
2. Operated the farms located in the best land classes and who used their lands more intensively.
3. Obtained the highest tonnage of sugar cane per cuerda.
4. Utilized farm labor with the highest degree of efficiency.
5. Operated the farms most specialized in the sugar cane enterprise.
6. Had the farms which were mechanized to the highest extent and owned practically all the irrigation equipment of the area.
7. Operated farms located at the very side of, or crossed by, a paved road.
9. Were the oldest in age; that is, 61 years or older.

From the standpoint of capital investment, it was found that the farms which had the highest per cent return on capital were those that:

1. Ranged between $5,000 to $10,000 in total capital investment, had between 60 to 100 total cuerdas in farm, harvested between 50 to 100 cuerdas in sugar cane, and employed from 5 to 10 men during the year. By no means were these the largest in size.
2. Were located in the best economic land classes.
3. Obtained yields of sugar cane ranging from 21 to 25 tons per cuerda. These yields averaged second to the highest.
4. Utilized labor with the highest efficiency.
5. Were specialized to the highest extent in the sugar cane enterprise.
6. Were mechanized to the lowest extent. That is, those farms where the total investments in machinery and equipment constituted less than one per cent of the total farm capital.
7. Were operated by individuals who owned part of their business and acted as managers of the remaining part.
8. Were located at the very side of, or crossed by, a paved road.
9. Were operated by individuals ranging from 41 to 50 years of age.

As could be observed, the farms which were found to be the most successful from the standpoint of operator's returns were not in general the same ones which led from the point of view of capital investments. The first were found to be the largest sized farms while the latter were rather of a medium size. This is a particularly important point to be given full consideration in implementing a land tenure program for Southwestern Puerto Rico.

FARM CREDIT[7]

The financial conditions of the farmers studied in Southwestern Puerto Rico were very good, as shown by the fact that the average net worth was 93 per cent of the total assets even when the receivables from Agricultural Adjustment Administration payments were not included in the assets.

Of the farmers studied, only 67 reported mortgages, the majority of which were held by the Federal Land Bank and Land Bank Commissioner. Individual, sugar centrals and commercial banks were the other agencies holding mortgages on these farms. The Federal Land Bank charged the lowest rate of interest and held the largest mortgages.

[7] Source. Luis A. Nazario, A credit Study of the Lajas Valley, Puerto Rico, 1942–43. Thesis presented to the Faculty of the Graduate School of Cornell University in partial fulfillment of the requirements for the degree of Master of Science in Agriculture—1944. As courtesy of the Puerto Rico Agricultural Experiment Station, Mr. Nazario was permitted to analyze and use for his master's thesis the credit phase of this study.

Most of the short-term credit received by the farmers studied was for the cultivation and harvesting of sugar cane and cotton. Other short-term credit constituted only 7 per cent of the total.

The most important course of production credit for sugar cane was the sugar centrals. Mentioned in order of importance, the other sources of production credit found were: commercial banks, Production Credit Association and individuals. Sugar centrals provided all the harvesting credit regardless of which agency made the production loan. No interest was charged on this credit. Harvesting credit may be looked upon as an advance payment on the crop. The sugar centrals generally charged a 7 per cent interest for the production credit, while governmental agencies charged only from 4 to 5 per cent. Sugar mills granted the smallest amount of credit per cuerda and per ton for sugar cane cultivation. The farmers who received credit from them had 22 per cent lower yields than those receiving credit from other agenices.

Credit for cotton was supplied mainly by the Emergency Crop Loan Office, the Production Credit Association and the Farm Security Administration. Commercial banks loaned mostly to large farmers who secured their loans by notes. No credit was reported to be granted for livestock raising or milk production even though they were important enterprises in some of the farms studied.

Of the farmers growing sugar cane, 14 per cent obtained no credit for this crop, 17 per cent received credit for production only and 16 per cent just for harvesting purposes. The average total amount borrowed per cuerda was \$56, of which \$37 were for production and \$19 for harvesting. On a per ton basis, the total was \$2.78, of which \$183 was for cultivation and \$0.95 for harvesting.

The great majority of the short-term loans were secured by the crops themselves and some loans were made with no security at all. One fifth of the loans made were guaranteed with other securities such as Agricultural Adjustment Administration payments, crops and animals, crops and equipment, notes, and even by real estate.

By the end of the crop year, 86 per cent of all the short-term loans received by farmers were paid in full and only 2 per cent did not make a payment on the principal, but even these paid the interest due.

Even though no relationship was found to exist between rates of production or size of business and the amount lent per ton or per cuerda of sugar cane, a definite tendency for the larger farms with better yields to borrow more for sugar cane than the others was observed. Furthermore, there was no definite relationship between per cent income from livestock or sugar cane and the amount of credit received by farmers.

To conclude, there is not much risk involved in lending to farmers in the Lajas Valley for sugar cane cultivation and harvesting. Farmers, in gen-

eral, are in very good economic condition; and, furthermore, the sugar centrals, which are the most important source of this type of credit, have complete control of the crop.

It is a fact that the majority of the farmers studied rated higher the convenience of borrowing from the sugar centrals rather than from the governmental agencies at lower interest rates. The lack of knowledge on the part of a great number of farmers in regard to the proper way of obtaining credit from the government-sponsored agencies may partly explain this preference. Furthermore, farmers are very suspicious of the large amount of red tape which usually characterizes these agencies. It is very advisable, therefore, that this situation be well understood by the Government and that a well organized educational campaign aimed towards the proper orientation of farmers on all credit aspects be initiated.

CONCLUSIONS AND RECOMMENDATIONS

The general objective of this study was to provide the Lajas Valley Committee with basis data relative to the farm management and land use aspects in Southwestern Puerto Rico. This information is expected to serve as a partial guidance to the above-mentioned governmental officials in delineating the general development program for the Lajas Valley Area. In spite of the fact that other important findings were observed throughout the study which are more related to the techniques of farm management and land use, this section is to be restricted only to the discussion of two main problems: irrigation and land tenure. It seems to the author that these are the major points of special interest to the Committee.

The following are perhaps two general questions for which the Committee very probably will like to find an answer. First, would the establishment of an irrigation project result in benefits for the area and for the Island as a whole? Second and last, what land tenure pattern would it be best to implant in the area if the irrigation system is found to be feasible? Our study was not specifically intended to answer these questions in full. However, it may enlighten the problems to some extent.

This study revealed that in the farms of the area where irrigation was practiced average yields of 28.9 tons of sugar cane or 3.67 tons of sugar per cuerda were obtained. On the other hand those farms where no irrigation was carried on had average yields per cuerda of only 17.4 tons of sugar cane or 2.24 tons of sugar. These higher yields could be mostly attributed to the irrigation practice followed, since the quality of the land, as measured by its value per cuerda was practically the same. Considerable sugar cane lands suited for irrigation were not irrigated at all. This suggests the fact that if all the lands fitted for irrigation were irrigated the total production of the area would increase to levels which would undoubtedly reflect in the general economy of the Island as a whole.

From the point of view of capital investment irrigation, however, was not such a good paying proposition for the farmers who made the investment. For instance, it takes more years, on these farms than on those where irrigation was not practiced for the total receipts obtained in the crop year 1942-43 to equalize the total capital invested, as shown by a capital turnover of 3.1 and 2.6 respectively. The per cent return on capital was also lower for the farms irrigating; that is, 11.6 as compared to 14.3 for the others. This suggests that the farmers themselves could not economically afford to incur such large investments. Undoubtedly these investments would increase substantially the total farm income of both the area and the Island, but would need to be financed in some way by outsiders, in our case, the Government. It also indicates that government investments should be made from a long time point of view and, furthermore, that the arrangements with the farmers in the area which may use irrigation services should be carefully worked out having mostly in mind the idea that it be a blessing to them rather than an economic burden.

If the Government decides on the establishment of an irrigation system, then, the next decision to be made is that relative to the land tenure pattern for the area which will be most in agreement with the policy of helping the largest possib'e number of families. The main aspect of the land tenure problem as seen by the author, is mostly a question of the size of farm unit which will best serve the economic and social objective of securing the highest returns as well as the best distribution of both the present and potential income of the area.

It is true that a large number of families could be helped by the establishment of small size farm units. However, it has been demonstrated in this and in many other studies that a farm unit needs sufficient size of business in order to be profitable. As a rule, the larger farms make the better profits because of their advantage over small ones of being able to use more efficiently the factors of production and marketing. This last statement has been found to be true only within certain limits. For instance, in years of unfavorable weather or very low prices the largest farms suffer the largest losses. Furthermore, beyond a certain top limit of size, labor is less efficiently used.

This study definitely demonstrated that the largest sized farms operated by ten or more men during the year were found to bring the highest labor income. These farms had an average total capital invested of around \$156,000, a total farm acreage of a little over 850 cuerdas, out of which 225 were in sugar cane, and produced a little over 5,800 tons of cane. The return on labor per man which is to some extent a measure of the possible standard of living of the persons employed on the farms, amounted to an average of \$778 on these farms. These farms made plenty for the owners but helped a relatively fewer number of needy families.

The farms which made the highest returns on labor per man were those which employed between 5 to 10 men during the year; had an average total acreage of 167 cuerdas, harvested around 30 cuerdas of cane, produced around 600 tons of cane, and had an average total capital of almost $23,000. Their return on labor per man averaged $786, and their labor income was very close to $2,500.

The return on labor per man of the above farms was slightly above that obtained in the very largest ones. Furthermore, these farms obtained the highest per cent return on capital. This fact may indicate to some extent that if one is interested in high returns per man and high returns on the capital invested there is not much point in operating units in the area which may exceed the size of these farms. It further suggests to those in charge of implementing the land tenure program of the Island the possibility of giving some consideration to the advisability of establishing proportional benefit units of this size.

A farm unit employing 5 to 10 men will combine to a larger extent the advantages of both the large-scale and the moderately sized operations. Besides the advantages of making economies in the use of labor, equipment, capital and in large-scale buying and selling, they will also have the benefits derived from the availability of governmental technical experts and highly trained employees. In addition, because of the fact that these units will be looked upon by the laborers as something closer to the individual type of operation, they may develop more interest in the business; and in emergencies they may put in longer hours of work. There is no doubt also that decisions are made more quickly in this type of farm operaton than in the large-scale ones.

If the efficiency in the organization, management and operation of the suggested units is maintained, they will bring the highest returns per man, the highest return on the capital invested and at the same time will conform to the social objective for which they were created.

As indicated before, the ultimate objective of any development program for the Lajas Valley Area is the social enjoyment of land by the people in general. The achievement of this ambitious goal involves the greatest possible coordination and cooperation among the different branches of the Government which may be responsible for the execution of the plan. In addition, an integrated planned social and economic reorganization can only be carried out successfully through the development and utilization of leadership, both professional and voluntary. Real leadership is necessary not only to perserve confidence in the possibility of crystallizing the development plan but also to get active participation from the people themselves and to make them conscious that the success of the program is an issue of vital importance in their lives.

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STUDIES ON SILAGE IN PUERTO RICO. I. METHODS OF ENSILING AND RESULTING QUALITY OF MERKER, CANE TOPS AND PARA GRASS SILAGES

By L. RIVERA BRENES,[1] F. MARCHÁN,[2] and E. DEL TORO.[3]

INTRODUCTION

Recurrent deficiencies in both quantity and quality of forage crops and the use of large amounts of costly concentrate feeds are among the major factors responsible for high costs in milk production in Puerto Rico. A wasteful use of forage is the inevitable result of the present method of forage cropping. In the areas where soilage forage is used, it is nearly impossible to feed grass at the optimum stage of maturity and at the same time avoid both shortage during the dry season and over-abundance during favorable growing periods. In pasture areas the problem is even more acute, requiring a large acreage for pasture and also the use of large quantities of concentrates during the dry-weather months in order to keep the cattle alive.

Furthermore, under present methods of forage cropping land is not economically used. Sufficient land must be set aside to provide minimal quantities of forage of any quality during dry seasons. The economy of Puerto Rico will profit if these lands were freed to be put to a more intensive use.

Proper methods of storage are necessary to provide sufficient forage of good quality during the whole year. The making of hay is difficult due to frequent rains during the growing seasons and because the grasses now used are too thick-stemmed to dry and handle as hay, unless they are chopped and dried artificially. Because of the climate, the crops now grown, and the availability of inexpensive molasses, the preservation of grasses as silage offers a rational solution to the problem.

At present there are few silos in use in Puerto Rico. Information concerning the usefulness of presently grown crops, methods of making silage of these crops, and the economic value of silage in Puerto Rico is meager.

It was the purpose of this study to secure information concerning the possibility of making silage of grasses grown in

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Puerto Rico, the best methods to be used, the changes and losses that take place in the silo, and the quality of the resulting silages as mesaured by chemical analysis, palatability and appearance.

Literature Review

The literature concerning the preparation of silage and the losses encountered in silage are reviewed by Woodward [10] et al and LeClerc.[6]

May [7] erected the first silo in Puerto Rico at the Federal Experiment Station, Mayagüez. He secured good results using corn as ensilage but poor results with cane tops, Guinea grass and Para grass (Malojillo).

Experimental

Six concrete silos 7½ feet in diameter and 15 feet high, each having a capacity of 7 to 10 tons of fresh forage were used. A series of holes was made in the walls at random points at 4, 6 and 10 feet from the top. These holes were fitted with 2-inch capped pipes and were used for drawing samples for chemical analysis.

FIGURE 1.—Experimental Silos. Capacity 7 to 10 tons of green forage.

Grasses were cut by use of a large-size Gehl cutter and were blown into the silos in the usual manner. At the same time, molasses was added by means of a pump attached to the silage cutter and its rate of addition regulated by means of a valve. Water was added by diluting the molasses, care being taken to insure the addition of the correct amount of molasses.

One man was used to distribute the cut grass and to trample it according to the specifications of each trial. The amount of fresh grass placed in each silo was estimated by averaging the weights of two ox carts of grass and multiplying the average by the number of carts used.

Para grass (*Panicum barbinode*), cane tops (*Sacharum officinarum*) and Merker grass (*Penissetum purpureum* var. *Merkerie*), were the forages used. Special emphasis was placed on the latter due to its increasing importance as a crop in Puerto Rico. Observations were made on the factors affecting the quality and quantity of the silage. Such factors were: length of chopped grass, moisture content of the grass, thoroughness of packing, and the maximum length of time which could elapse between partial fillings of the same silo.

Chemical analyses of the fresh grass (plus molasses when it was added) and of the silage were made from random samples of the material. The bag method was used for analysis in one trial. Moisture was determined by placing samples in an oven set at 70°C and equipped with a turbo blower. The pH was measured with a MacBeth pH meter. Other analyses were made according to the official methods of the Association of Official Agricultural Chemists.[8] Calculations of the percentage of total nutrient losses were made by using the approximate amount of nutrients in the ingoing dry matter (total) and the amount of nutrients in the dry matter that was recovered as edible silage.

Factors considered in the evaluation of the quality of the silage were: pH, odor, color and palatability. The latter was tested by a series of feeding trials in which silage and soilage of the same quality were used. All silos were opened thirty days after filling.

Nine silos were filled: six with Merker grass with ten per cent molasses, two with Para grass with five and ten per cent molasses, and one with cane tops to which no molasses was added.

The forage was chopped ½ inch long. This length of cut ½ inch or shorter is recommended to insure packing. In silo No. 1 a man was used to level and trample the material at intervals of three ox carts chopped; in the rest of the silos the man was kept leveling and trampling constantly.

Water was added to all silages except to No. 9, at a rate of 3 to 5 per cent of the approximate weight of the forage. The amount varied according to the operator's judgment of dryness of the material.

Results and Discussion

In Table 1 the approximate total weight of material put into four of the experimental silos is shown.

TABLE No. 1

APPROXIMATE TOTAL WEIGHT OF MATERIAL PUT INTO FOUR OF THE EXPERIMENTAL SILOS

Silage No.[1]	Number of ox carts of grass used	Ave. wgt. of two ox carts lbs.	(Approximate) total weight of forage	Molasses Per Cent	Total wgt. of molasses	Amount of water added lbs.	Water added by wgt. of forage Per Cent	Total wgt. of material
1.	12	1,488	17,856	10	1,785	799	4.50	20,440
4.	10	1,850	18,500	10	1,850	650	3.50	21,000
5.	10	1,187	11,870	10	1,187	513	4.50	13,[illegible]00
9.	10	1,089	10,890	10	1,210	000	0.00	12,100

[1] Merker grass used.

Due to the fact that the molasses pump was adjusted to spray at a rate of ten per cent when the chopper was fed continuosly, it appears that the total amount of forage calculated is approximately accurate. The fact that there was no bottom spoilage in any of the silos indicates that the amount of water was not excessive.

Chemical analyses of the ingoing grass and the resulting silage are presented in Table 2.

TABLE No. 2

PROXIMATE ANALYSES OF THE GRASSES PLUS MOLASSES AND THE SILAGES

No. of silo	Grass	Date Ensiled	No. of Samples	Analyses: Molasses	Moisture	Dry matter	Ash	Crude protein	Ether extract	Fiber	N. F. E.[4]
				Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
1	Merker	12-6-46	1		76.30	23.70	10.59	9.47	2.37	31.55	46.02
	Silage		2	10	76.70	23.30	11.36	9.53	3.52	32.22	43.39
2	Merker	3-13-47	2		76.25	23.70	6.51	5.13	2.25	35.54	50.58
	Silage		7	10	74.23	25.77	8.51	5.37	2.90	33.55	49.67
3	Merker	3-18-47	2		72.20	27.80	6.55	5.01	2.14	36.53	49.77
	Silage		7	10	72.76	27.24	8.30	5.21	2.70	33.15	50.64
4	Merker	6-25-47	11		82.40	17.60	11.25	5.88	2.13	33.56	47.18
	Silage		8	10	79.60	20.40	12.39	6.12	2.25	27.68	51.56
5	Merker	7-31-47	7		73.66	26.34	10.23	5.26	2.23	32.53	49.75
	Silage		8	10	72.72	28.00	13.55	6.28	2.41	28.08	49.88
6	Cane tops	3-7-47[1]	2		77.70	22.30	9.03	6.37	2.36	31.71	50.53
	Silage		7	....	76.86	23.14	8.93	6.75	1.74	34.76	47.82
7	Para grass	11-26-47	5		73.24	26.76	15.75	9.10	1.56	24.76	48.83
	Silage		6	10	71.89	28.11	18.28	8.54	1.27	25.37	46.54
8	Para grass	11-28-47[2]	5		78.42	21.58	15.95	7.84	1.22	27.50	47.49
	Silage		6	5	79.07	20.93	16.42	6.64	1.15	30.40	45.39
9	Merker	11-4-47[3]	5		69.78	30.22	10.40	7.30	1.62	34.19	46.49
	Silage		5	10	67.51	32.49	10.72	6.71	1.84	33.49	47.24
(9)	Bag sample		1		69.10	30.90	10.83	7.06	1.71	34.58	45.72
	Silage		1	10	68.10	31.90	10.19	5.81	2.01	36.06	42.93

[1] No molasses used.
[2] Five per cent molasses.
[3] No water was added to this silage.
[4] Nitrogen free extract.

Chemical composition of forage grasses has been shown to vary with the stage of maturity, soil conditions and climate.[5] Young plants are characterized by their high protein content and high digestibility of their dry matter. The earlier the crop is harvested, the higher will be the protein and moisture content, but too early a harvest of any crop will reduce the tonnage.[4] In general, the same rules may apply as regards time of cutting for silage as for soilage. The feeding value of silage will depend upon the feeding value of the fresh material, and the conditions under which it is ensiled.[1]

As all grasses are comparatively low in protein content, the soundest procedure would be to harvest the crop at a point where the maximum tonnage can be obtained with the least reduction in quality. In Puerto Rico, Merker grass is in good cutting condition just before bloom: 60 to 80 days old. Variations will arise due to farming practices and changes in weather conditions. Para grass is somewhat different; before bloom it is too short for cutting. The best time to cut is right after blooming, except for very fertile soils where good growth will permit earlier cutting. The time will vary between 50 to 70 days. For cane tops, the farmer has to wait until the sugar cane harvest.

The proximate total losses for Merker silage are presented in Table 3.

TABLE No. 3

APPROXIMATE LOSSES IN MERKER SILAGE PRESERVED WITH TEN PER CENT MOLASSES

Silage No. and date ensiled	Grass, molasses and water	Dry matter	Total Dry matter	Intangible loss	Loss	Edible silage	Spoiled silage	Loss	Total loss
	Lbs.	Per Cent	Pounds	pounds	Per Cent	Pounds		Per Cent	Per Cent
12-6-47									
1- Ingoing	20,440 00	23.70	4,844.28	759.10	15.67	....	....	....	....
Outgoing	17,533.00	23.30	4,085.19	....	....	16,213.00	1,140.00	6.50	22.17
6-25-47									
4- Ingoing	21,000.00	17.60	3,696.00	365.50	9.89	....	....	....	....
Outgoing	16,326.00	20.40	3,330.50	....	....	15,336.00	990.00	6.06	15.95
7-31-47									
5- Ingoing	13,600 00	26.34	3,582.24	277.12	7.74	....	....	....	....
Outgoing	11,804.00	28.00	3,305.12	....	....	10,833.00	971.00	8.23	15.97
11-4-47									
9- Ingoing	12,100.00	30.22	3,656.62	258.17	7.06	....	....	....	....
Outgoing	10,460.00	32.49	3,398.45	....	....	9,620.00	840.00	8.03	15.09
Bag Sample 11-4-47									
Ingoing	471.50[1]	30.90	145.70[1]	4.67[1]	3.20	....	....	....	....
Outgoing	442 10	31.90	141.03	....	....	....	....	....	....

[1] Weight in grams.

The importance of good packing was indicated by the results of total losses in silage No. 1 as compared with the other three. The larger losses in silo No. 1 were probably due to the fact that leveling and tramping were done at intervals instead of having a man constantly in the silo, as in the other three; packing was not as good as in the others.

Table 4 presents a summary of total nutrient losses compared to the losses reported by other workers in the field.

TABLE NO. 4

SUMMARY OF NUTRIENT LOSSES IN PERCENTAGE LOSS OR GAIN

	Dry matter	Ash	Crude protein	Ether extract	Fiber	Nitrogen free extract
Silo No. 1	−22.02	−16.34	−21.56	15.83	20.36	−26.47
Silo No. 4	−15.40	−6.82	−11.85	10.57	23.17	−13.86
Silo No. 5	−17.50	+7.66	−1.51	10.84	28.79	−17.29
Silo No. 9	−14.52	−14.52	−21.43	−2.92	16.27	−13.14
Bag sample (9)	−3.30	−8.94	−20.40	+13.65	+8.98	−9.12
Le Clerc (6) citing Henry and Wall and Woodman and Amos[1]	−5.8 to −18.1	+3.1 to −6.8	+2.0 to 12.2	+59.0 to −122.0	+0.90 to 11.80	−16.20 to −24.90
Ragsdal and Turner (9)	−2.1 to −18.1	−11.7 −15.7	+5.1 to −38.4	+49.4 to −20.3	+6.70 to −14.6	−5.8 to −22.5

[1] Using bag samples.

Results obtained on total losses and nutrient losses are within the range of the findings of other investigators [2, 3, 6, 9]. There is a wide variation in the percentage of losses or gains. It is apparent that appreciable quantities of nutrients are lost and that the losses silage undergoes depend upon the size of the silo, amount of silage and on the methods and techniques used.

The results obtained on pH values in three of the experimental silos are presented in tables 5 and 6.

TABLE No. 5

pH VALUES AT DIFFERENT INTERVALS AND AT DIFFERENT LEVELS. MERKER GRASS, TEN PER CENT MOLASSES

Silo Number	Interval from ensiling days	Distance from top feet[1]	pH values
		10	3.7
No. 9	6	6	3.8
Filled 11-4-47		4	4.0
	9	6	3.9
		4	4.0
	13	10	4.1
		6	4.2
		4	4.4
	21[2]	10	4.3
		6	3.8
		4	4.0
Mean			3.95

[1] Samples taken through the holes in the sides of the silo at those levels.
[2] No more samples were taken from there on due to mold contamination around sampling holes

TABLE No. 6

PH VALUES AT DIFFERENT INTERVALS AND AT DIFFERENT LEVELS MERKER GRASS TEN PER CENT MOLASSES

Silo Number	Interval from ensiling days	Distance from top feet[1]	pH values
No. 5	35	2.0	4.1
Filled 7-31-47	37	3.0	4.1
	39	5.0	4.2
	43	6.0	4.0
	46	7.0	4.3
	50	9.0	4.0
	53	10.0	3.8
	57	13.5	4.1
Mean			4.05
No. 4	71	2.0	4.3
Filled 6-25-47	73	3.0	4.3
	75	5.0	4.0
	79	6.0	4.1
	82	7.0	4.6
	86	9.0	3.8
	89	10.0	3.6
		13.5	4.2
Mean			4.01

[1] Samples obtained as the silage was taken out for use.

The pH values obtained indicate that Merker silage was preserved in excellent condition. These values are in agreement with the findings of other investigators which give the same range of pH values for good silage [3, 6, 10].

Due to the natural characteristics of Merker grass, which has light leaves and hard bulky stems; Para grass, which has light and hollow stems; and cane tops, which are bulky and nearly always quite dry; chopping to ½ inch or less, the addition of some water, especially toward the top of the silo, and continuous tramping are essential factors to be considered when ensiling in order to get good packing and prevent excessive losses (especially top spoilage and spoilage toward the walls of the silo).

Wilting is not advisable for the reasons pointed out above; the material will become too light to attain good packing, even with tramping. In addition, the hot tropical sun will destroy a large portion of the carotene and part of the protein during the wilting period. It is true that too much moisture will cause some spoilage in the bottom of the silo, but too little moisture is much more serious than too much.

Merker grass plus ten per cent molasses produced a very palatable "green, fruity" [6] silage with a pleasant molasses odor. Para grass with five or ten per cent molasses produced a "sweet, dark-brown" [6] silage of a much lower quality than Merker silage, as regards color, odor and palatability. Of the two Para grass silages, the ten-per-cent molasses silage was more palatable and had a more pleasing odor than the five-per-cent silage, as indicated by the fact that the cows consumed the former more readily. Para grass has the disadvantage that dirt is nearly always found in it due to its habit of growth: close to the ground and in swampy places. This, without doubt, affects quality adversely.

Cane tops were ensiled satisfactorily without molasses. They produced a coarse silage, lower in quality than Merker. Cattle ate it and because cane tops are harvested during the dry season, the silage makes a good substitute for Merker or Para grass soilage and other pasture crops which are affected by drought. A large quantity of sugar cane is grown in the Island and cane tops are very easy to get during the harvest season that lasts from three to five months.

Para grass and cane tops were ensiled satisfactorily, contrary to the findings of May [7] who used a very dry material adding no water. Very poor packing was probably attained.

Molasses has been considered one of the best, if not the best, preservative for silage [1, 4, 6, 10]. In Puerto Rico, where sugar

cane is the main cash crop, molasses is cheap, a little less than two cents a pound, and easy to get. Many of the dairymen are also sugar cane growers and have a share of the molasses produced from their cane. They are, therefore, in a very favorable position to face the scarcity of pasture and soiling crops during the dry season by erecting silos of adequate size for their herds and preserving grasses with molasses.

Observations tend to indicate that, probably due to the warmer temperatures in Puerto Rico, the interval to resume filling the silo, after it is partly filled, should not exceed more than 24 hours because a very dense layer of molds will grow very rapidly on the uncovered portion. This moldy layer has to be removed before resuming the filling operation, consuming extra labor and increasing the loss of material.

Summary and Conclusions

Merker grass, Para grass and cane top silages were made satisfactorily using experimental silos $7.5' \times 15'$. The commonly recommended techniques, except wilting, can be followed in Puerto Rico. Observations tend to indicate that the forage should be put into the silo within a few hours after cutting. Due to the natural characteristics of the native-grown grasses and of the excessively hot sun, wilting it not advisable: the material becomes too light to attain good packing and there is a probable reduction in the nutritive value.

Unless very heavy weights are put on top of the ensiled material (this is troublesome and costly in tower silos), water must be added to insure good packing especially toward the top of the silo. Experience will help to determine the amount of water to be added.

More detailed studies on total losses, nutrient losses and pH values were made with Merker silage. The results obtained were within the range reported by investigators in the United States.

Further observations tend to indicate too, that intervals between fillings should not exceed more than 24 hours to avoid excessive losses due to moldy silage. The tropical temperature seems to favor the rapid growth of molds.

With respect to odor, color, palatability and pH values, very good silage was obtained from Merker grass. Good cane tops

and Para grass silages were obtained too, but not of the same quality as Merker silage.

Molasses can be used as a preservative up to ten per cent. It increases palatability and nutritive value of the silage.

Results obtained with Merker grass silage probably apply to the other forage grasses in the Island, taking into consideration the results obtained in the present work as compared to the results obtained by others with grass and legume silages.

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THE UTILIZATION OF GRASSES, LEGUMES AND OTHER FORAGE CROPS FOR CATTLE FEEDING IN PUERTO RICO

I. Comparison of Guinea Grass, Pará Grass "Malojillo" and a mixture of Pará Grass and Tropical Kudzu as pasture crops

By LUIS RIVERA BRENES.[1]

INTRODUCTION

The success of the cattle industry in Puerto Rico is limited to a large extent by the lack of adequate sources of feed. Based on over 400,000 head of cattle, it is the second most important agricultural industry on the Island. In addition there are over 500,000 acres of cleared pasture land, which constitute about two fifths of the available arable land and whose efficient utilization is entirely dependent upon a well-managed cattle industry.

In Puerto Rico, the dairy cattle industry is somewhat regionalized. Intensive commercial milk production is mainly restricted to milk-shed areas sorrounding the urban centers. Dairy management is based on the use of Pará or "malojillo" (*Panicum purpurascens*) and Merker (Pennisetum purpureum, *var. Merkerii*) grasses cut for soilage with the supplemental feeding of mixed concentrate feeds.

Beef production is generally restricted to the grazing area of the southern coast and in reality is primarily a by-product of the production of workstock. Guinea grass is the prevailing pasture crop in this section.

In the mountainous areas cattle grazing is dependent upon miscellaneous grasses of low yield and little nutritive value.

Soil and climatic conditions on the Island are quite variable. In the north coastal region the rainfall is heavy and the soil is acid. In the south, the soil is alkaline and fertile, but its use is limited by a lack of adequate rainfall. The central portion of Puerto Rico has acid soils of low productivity and the climate is quite humid. The climate of the whole Island is characterized by periods of low rainfall in the winter and early spring and of abundant precipitation during the summer and fall. The dry period is much longer and more severe in the southern coastal region than in the other parts of the Island.

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[1] Associate Animal Husbandman.

Note: Mr. Juan Pastor Rodríguez, Associate Agronomist, was in full charge of the agronomic work required for this study.

The diet of the people of Puerto Rico is low in protein from animal sources. During 1944–45 [1] the per capita consumption of meat and fish, including imported products, was only 63 pounds. Twenty per cent of the 141 pounds of milk used per person was imported. For the same period, the per capita consumption of the United States was, on an average, 70 pounds of beef [7] and 440 of milk.[5]

Improved pasture and soilage crops should lower feed costs and increase the production of much-needed animal products, thus improving the diet of the Puerto Rican people to a considerable extent.

LITERATURE REVIEW

Information as to the best method of utilizing local grasses, legumes and other forage crops in the feeding of cattle in Puerto Rico is scant.

Axtmayer et al,[2, 3, 4] made studies on the nutritive value of some grasses and legumes grown at the Agricultural Experiment Station farm, which indicate that the grasses commonly used as forage crops are relatively low in protein content. Unpublished results obtained at the above-mentioned Station [9] have shown that when heifers were pastured on Guinea and Pará grasses they made better gains than when pastured on paspalum (*Paspalum hartwegianum*). Other results from the same project indicated that Merker and Elephant (*Pennisetum purpureum*) grass were not suitable for pasturing.

No experimental data have been published for Puerto Rico about the carrying capacity of any particular pasture previous to this work.

In the United States different methods of pasture evaluation were used until 1940, when a standard method was adopted by the Pasture Research Committee.[8]

EXPERIMENTAL

The forage grasses used in this grazing trial were: Pará grass, or malojillo (*Panicum purpurascens*), Guinea grass (*Panicum maximum*) and a mixture of Pará grass and tropical Kudzu (*Pueraria phaseoloides*).

Pará and Guinea grasses are common on the Island. Tropical Kudzu, a legume native to Malaya, was introduced to the Island by the Soil Conservation Service in 1940. Telford [10]

reported that Kudzu is best suited to the parts of the Island having at least 50 inches of rainfall per year.

At the start of the trial the condition of all the grasses and Kudzu was satisfactory. The plots of Para, Guinea and Para-Kudzu mixture had been planted three, two and one years prior to the start of the trial.

The grasses and the mixture were planted in three blocks of three one-acre plots; each plot planted to a different forage. Every plot was subdivided into three lots, each one-third of an acre in area. The fencing arrangement of the plots allowed the animals in each lot access to shade, water and mineral mixture, (ad lib.). The position of each crop within a block was selected at random. The soil of the experimental field was a well-drained Fajardo clay. In order to decrease the acidity of the soil, lime was added to each lot to bring its pH to 6.5, two years before this study was initiated. No other fertilizer was used at any time.

Nine pure native heifers were used. They were uniform in age, six to seven months old, but varied in weight.

The heifers were weighed for three consecutive days at the beginning of the trial and for three consecutive days every time they were moved from one lot to the next.

One heifer was put in the No. 1 lot of each respective grass plot and was moved from one lot to the next in their own plot when any one of the lots in the entire experiment was grazed out. They were taken out of the experiment when they were of breeding age, 18 to 19 months old.

All lots that had some good roughage left at the time of moving the animals to the next lots were clipped with a "machete" and the residue weighed. Before clipping, samples were taken for analysis. Sub-samples of grass from the middle and the four corners of the lot were taken and a composite sample made from them. Moisture in the samples was determined by drying to constant weight at 70°C. In the analyses of all of the samples the methods used were those given by the Association of Official Agricultural Chemists.[6]

Computation of total digestible nutrients produced by the different grasses and the carrying capacity was made according to the recommendations of the Pasture Research Committee of the American Dairy Science Association.[8]

Analysis of variance and covariance were done according to the methods given by Love.[11]

Results and Discussion

Due to seasonal effects, the experiment was divided in three periods which were marked by the following: First period, with the three grasses under trial; second period, without the Pará grass; and the third period, where an extra heifer was put in the Pará grass-Kudzu mixture.

Results of the three grazing periods are presented in Table 1.

Table No. 1

WEIGHT GAINS IN PER GROUP, MEAN GAIN PER ANIMAL AND LEAST SIGNIFICANT DIFFERENCES

Grasses	No. of heifers	Initial weights of groups	Weight of group at the end of periods	Gains of groups in pounds	Mean gain in weight in pounds per animal
First Period 12-11-45 to 3-28-46					
PK*	3	843.17	1,064.17	221.00	73.7
P	3	796.34	860.34	64.00	21.3
G	3	694.66	730.00	35.34	11.8
Least Significant Difference Between Means:					
At the 5 per cent level					28.14
At the 1 per cent level					46.68
Second Period 4-23-46 to 6-28-46					
PK	3	1,060.84	1,541.16	480.32	160.10
G	3	774.00	1,140.83	366.83	122.30
Least Significant Difference Between Means:					
At the 5 per cent level					143.12
Third Period 8-27-46 to 10-23-46					
PK	6	2,778.16	3,156.34	378.18	63.06
G	3	1,140.83	1,292.33	151.80	50.60
Least Significant Difference Between Means:					
At the 5 per cent level					104.65

*PK—Pará grass-Kudzu mixture.
P—Pará grass alone.
G—Guinea grass alone.

During the first period, the heifers on the mixture plots made significantly better gains than those on the other grasses, as shown in Table 7. A covariance analysis indicated that due to the higher initial weight of the animals in the mixture plots they gained 0.276 pounds more per pound of excess weight than the others. However, the gains were high enough to be significant even after making allowance for this. For the sec-

ond and third periods the gain differences were not high enough to be statistically significant.

At the end of the first period Pará grass was eliminated from the trial because it was severely affected by the drought. Indeed, even before starting the test, it was believed that the place was too high and dry for the Pará grass, which is best grown in low wet soils.

Drought did not seriously affect growth in the mixture plots. A very good mat was formed which could withstand close grazing and trampling and hold more of the moisture in the soil. The probable addition of nitrogen by the legume may have resulted in a better pasture.

Table 2 presents the chemical analyses of the different grasses, the mixture, and the plants from the mixture separately for the whole trial.

No samples were taken from plots that had very little roughage left or were completely grazed out. Samples of the grasses and the mixture were taken as explained before, all through the three periods, but the samples of Kudzu and Pará grass separated from Kudzu were taken in the third period. In all probability this is the explanation of the difference in moisture content and some other of the constituents in the analyses.

TABLE No. 2

AVERAGE ANALYSES OF THE DIFFERENT GRASSES DURING THE WHOLE TRIAL IN PER CENT, DRY BASIS

Grasses	No. of samples	Moisture Per Cent	Ash Per Cent	Crude Protein Per Cent	Fat Per Cent	Fiber Per Cent	Nitrogen Free Extract Per Cent
Pará grass	9	77.93	8.56	4.91	1.18	33.83	51.53
Guinea grass	15	77.10	12.56	5.76	1.45	32.30	4[illegible].10
Pará grass and Kudzu	9	75.55	8.05	10.94	1.76	33.09	46.10
Kudzu alone*	12	77.50	8.14	17.34	2.02	34.21	38.27
Pará alone*	(12)	77.93	9.83	9.00	1.68	30.50	49.00

* Para grass or Kudzu separated from the mixture.

Kudzu is quite high in protein content and the Pará grass growing with it is higher in protein than when growing alone. The analysis of the mixture presents a more or less intermediate situation showing quite an improvement.

Guinea grass gave a much better analysis than Pará grass alone especially as regard minerals and protein.

The most interesting fact to be observed is the increase in protein content of the Pará grass in the mixture, as compared to the Pará grass growing alone.

The weights of the clippings and the dry matter in pounds for the whole trial are presented in Table 3. The weights of the samples taken for analysis were included.

TABLE NO. 3

WEIGHT OF CLIPPINGS AND DRY MATTER YIELDS OF GRASSES; EXPERIMENTAL PLOTS

Grasses	Clippings, lbs.	Moisture Content Per Cent		Dry Matter, lbs
		First Period		
PK	25,382.82	(9 samples)	75.55	5,961 60
P	7,426.57	(9 samples)	77.93	1,639 04
G	9,391.94	(15 samples)	74.10	2,432 51
		Second Period		
PK	13,572 73	(same as above)		3,318 53
G	540.52	(same as above)		139 99
		Third Period		
PK	2,512 00	(same as above)		614.18
G	248 00	(same as above)		64.23

Larger amounts of forage were clipped from the mixture plots in all the three periods, even with two heifers in the third period.

The data in Table 3 together with the data in Table 1 were used for the calculation of total digestible nutrients and carrying capacity of the three grasses which are presented in Table 4.

The calculations were made according to the recommendations of the Pasture Research Committee of the A.D.S.A. and adapted to our problem. As growing heifers were used in this experiment, some error may have been introduced regarding the nutrient requirements per pound of gain in weight, but it is not felt that this source of error invalidates our conclusions regarding the evaluation of the grasses with respect to their nutritive value and carrying capacity.

The constants used have been as follows:

Standard cow-day = 16 pounds of total digestible nutrients

$$\text{Carrying capacity} = \frac{\text{Standard cow-days per acre}}{\text{Days in grazing season}}$$

Dry matter 72 per cent digestible

3.53 pounds of total digestible nutrients for every pound of gain in weight

The three periods are put together to facilitate comparison.

TABLE No. 4

CALCULATION OF TOTAL DIGESTIBLE NUTRIENTS AND CARRYING CAPACITY FOR THE THREE PERIODS OF THE EXPERIMENT

Items	First Period			Second Period		Third Period	
	PK	P	G	PK	G	PK	G
1. Days in periods	106	106	106	126	126	67	67
2. Number of heifers	3	3	3	3	3	6	3
3. Total cow-days (1) x (2)	318	318	318	378	378	402	201
4. Total initial weight in p un ls	843.17	796.34	694.66	1,060.84	774.00	2,778 16	1,140.83
5. Total final weight in pounds	1,064.17	860.34	730.00	1,541.16	1,140.83	3,156.34	1,292.33
6. Ave. maintenance, lbs. $\frac{(4) + (5)}{2}$	953.67	828.34	712.33	1,301.00	957.42	2,967.25	1,217.08
7. Total weight-days (6) x (1)	101,089.02	87,804.04	73,506.98	163,926.00	120,634.92	198,805.75	81,544.36
8. TDN req. for maintenance, lbs. $\frac{(7) \times 7.925}{1000}$	801 13	695.85	598.39	1,299.11	956.03	1,575.54	646.24
9. Weight gain in pounds	221.00	64.00	35.34	480.32	366 83	378.18	151.50
10. TDN requirement for gain, lbs. (9) x 3 53	780.13	225.92	124.75	1,695.52	1,294.91	1,334.97	534.79
11. TDN requirements, lbs. (8) + (10)	1,581.26	921.77	723.14	2,994.63	2,250 94	2,910.51	1,181.03
12. TDN from residue, lbs	4,292 35	1,180.11	1,751.40	2,389.34	100.79	442.21	46.25
13. TDN yield of pasture, lbs. (11) + (12)	5,873.61	2,101 88	2,474.54	5,383.97	2,357.73	3,352.72	1,227.28
14. TDN yield per acre, lbs. $\frac{(13)}{\text{acreage}}$	1,957.87	700.63	824.85	1,794.66	783.91	1,117.57	409 09
15. Standard cow-days per acre $\frac{(14)}{(16)}$	122 36	43.79	51.55	112.17	48.99	69.84	25.57
16. Carrying capacity standard cow-days $\frac{(15)}{(1)}$	1.15	0 41	0.49	0 89	0.39	1.04	0.38

The results in Table 4 show the superiority of the mixture over Pará and guinea grasses in total digestible nutrients and carrying capacity. It more than doubles the yields of the other two separately. Guinea grass was similar to Pará in total digestible nutrients and carrying capacity, but was superior from the standpoint of drought resistance.

Taking all the results as a unit the carrying capacity for each grass under the conditions of the experiment were the following:

Mixture of Pará grass and Kudzu	1.02
Pará grass alone	0.41
Guinea grass alone	0.42

Analyses of the yields of total digestible nutrients per acre are presented in Table 5.

TABLE No. 5

MEAN TOTAL DIGESTIBLE NUTRIENTS YIELDS PER ACRE AND LEAST SIGNIFICANT DIFFERENCES FOR THE GRASSES DURING THE THREE PERIODS

Grasses	TND mean yield in pounds per acre
First Period	
PK	1,957.67
P	700.00
G	842.36
LEAST SIGNIFICANT DIFFERENCES BETWEEN MEANS:	
At the five per cent level	196.49
At the one per cent level	325.87
Second Period	
PK	1,701.89
G	784.03
LEAST SIGNIFICANT DIFFERENCES BETWEEN MEANS:	
At the five per cent level	466.18
At the one per cent level	1,075.27
Third Period	
PK	1,117.65
G	409.47
LEAST SIGNIFICANT DIFFERENCES BETWEEN MEANS:	
At the five per cent level	296.05
At the one per cent level	682.84

The differences between the mean yield of total digestible nutrients per acre among the grasses were statistically significant at the one and five per cent levels for the first and third

periods and at the five per cent level for the second period, in favor of the Pará grass-Kudzu mixture, as shown in Table 6. These results agree with those obtained for carrying capacity.

Summary and Conclusions

Pará grass or "malojillo" (*Panicum purpurascens*), Guinea grass (*Panicum maximum*) and a mixture of Pará grass and tropical Kudzu (*Pueraria javanica*) were tested as pasture crops by rotational grazing of 1/3 acre plots with native heifers which were 6–7 months of age at the start of the trial.

At the time the heifers were changed from one lot to another, the uneaten portions of the forages were clipped, weighed, and samples secured for chemical analysis. Observations were also made on the ability of the crops to withstand drought, trampling, etc.

Pará and Guinea grasses were similar as measured by gains of the animals, yield and carrying capacity. The Pará grass suffered severely during one phase of the trial due to a drought which affected it unduly because the grass was planted on high, well-drained, soil in contrast to its natural habitat. Guinea grass was not affected by the drought. This resistance plus its other desirable qualities indicates that Guinea grass is suitable as a pasture crop in Puerto Rico.

The combination of Pará grass and Kudzu was found to give the best results in total digestible nutrients, gain in weight of the animals and carrying capacity. There was some evidence to indicate that the mixture benefited the nitrogen balance of the soil and assisted in the retention of precipitation. The Kudzu contained approximately 17 per cent crude protein and Pará grass of the mixture had a higher protein content than that grown alone.

The results of this study indicate that Kudzu is a highly desirable crop to use in conjunction with Pará grass for pasture purposes.

Acknowledgment

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SODIUM FLUORIDE AS AN ASCARICIDE FOR SWINE RAISED ON THE GROUND

By

By Radamee Orlandi[1] and Fernando E. Armstrong.[2]

Parasitism in livestock is one of the major problems encountered by the animal husbandman in Puerto Rico. Swine are seriously affected with ascarides in this island. This is due to several factors some of which are: tropical temperature, relatively high average rainfall (above 70 inches) and, in general, poor management. In Puerto Rico pigs are raised on the ground with no provisions made to avoid or prevent parasitic infestations; and ascarides constitute a constant menace.

Several drugs have been used at one time or another as anthelmintics for swine. Oil of chenopodium has been used extensively since 1918 when Hall and Foster[2] first employed it as an ascaricide. According to Mote[6] its use has been hampered by the difficulty of administration and unreliability in certain cases. Hardwood, Jerstad, and Swanson[3] in 1938, reported on the efficacy of phenothiazine as an anthelmintic for swine. Their results varied from 0 to 100 per cent against ascarides. Phenothiazine has been stated to be an unreliable ascaricide, especially when fed to pigs harboring few ascarides, as reported by Mohler.[5] Swanson, *et al*,[8] reported that the drug is much less effective against immature than mature ascarides.

In 1945, Enzie, Habermann, and Foster,[1] described the use of different levels of sodium fluoride for killing ascarides in pigs. They found that when one per cent sodium fluoride, mixed with the feed, was given to twenty-six hogs, a 100 per cent ascaricidal efficiency was obtained. More recently Turk and Hale,[9] experimenting with large number of pigs, have reported on the ascaricidal properties of sodium fluoride. Their conclusions are based on the number of worms removed and subsequent appearance of the animals submitted to different treatments.

The present experiment was designed to test the value of sodium fluoride as an ascaricide for growing pigs kept on infested grounds and to investigate the possible efficacy of the

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drug to keep animals free from ascarides during their growing period, as well as to observe possible toxicity after repeated treatments.

Materials and Methods

Two trials were conducted to study the ascaricidal effect of sodium fluoride. The first trial also included the use of phenothiazine.

Trial I.—Thirty pigs, ranging in weight from 16 to 34 pounds (averaging 26 lbs.), and about two months of age, were divided into three groups of ten pigs each. The breeding of all groups was similar, litter mates being distributed among the groups in most cases. All of the pigs were kept in a ½-acre-infected lot at all times except when groups "B" and "C" were separated periodically for a few hours for treatment. Individual weights were taken at the beginning and end of the trial. All pigs were self-fed throughout the trial.

Group "A" served as control. Group "B" was weighed every three weeks and given one meal containing 0.2 gm. of phenothiazine per pound of body weight. Group "C" received a treatment of one meal containing sodium fluoride at the rate of 1 pound NaF per 100 pounds concentrate feed, every three weeks.

Trial II.—Was conducted during one year, following Trial I. The conditions were similar except that litter mates were used throughout, sodium fluoride was given at 4-week intervals, and the chances of infection were increased by furnishing a mud wallow.

Egg counts were made per gram of fresh feces secured directly from the rectum of each pig and by using the modified Stoll technique recommended by Hawkins.[4] Except for a short period at the start of the first trial, differential egg counts were made for ascarid and non-ascarid eggs.

At the end of each trial the hogs were slaughtered and visceral examinations made. In Trial I, some pigs from each of the three groups were spared and reincorporated into the breeding herd. One animal of group "A" died soon after the experiment was started.

All data were statistically analyzed by methods outlined by Snedecor.[7]

Experimental Results

The results for Trial I are given in tables 1, 2, 3 and 4.

Although differential counts were not made at the start of the trial, pigs of all groups were shedding ascarid eggs. Total egg counts prior to October 3, 1946 for groups "A", "B" and "C" showed no statistically significant differences. At no time did the numbers of non-ascarid eggs differ statistically among the groups in Trial I. On October 3, 1946 the ascarid egg count for group "C" was statistically significantly lower than for groups "A" and "B". Further statistical treatment for the number of ascarid eggs for Group C was not made as the numbers were so low. At no time did groups "A" and "B" differ statistically in number of ascarid eggs.

The results of the visceral examination are shown for Trial I in table 4. By the use of a chi square test it was found that groups "B" and "C" contained statistically significantly fewer pigs harboring ascarides than group A; and that groups B and C did not differ significantly. As previously mentioned, some hogs from each group were kept for breeding purposes and not slaughtered. As shown in table 2, two of the three hogs of group B, not slaughtered, were casting sufficiently large numbers of ascarid eggs to imply the presence of ascarides in their intestines. The two pigs of group "C" which were not killed were apparently free of ascarides. Thus, the probable numbers of infected hogs for groups "B" and "C" were four and 0, respectively. This apparent difference in the number of pigs dropping eggs is extremely important where the object of the treatment is not only to clear the pigs but to prevent continual reinfection of the ground.

Data collected on growth rates for groups "A", "B" and "C" showed that the mean growth rates for the various groups did not differ significantly.

Trial II.—The second trial gave results similar to those found in the first trial (tables 5 and 6).

TABLE NO. 1

NUMBERS OF ASCARID AND NON-ASCARID EGGS PER GRAM OF FECES IN THE CONTROL GROUP OF TRIAL I (GROUP A)[1]

Pig No.	Total of Eggs Per Gram of Feces			Differential Counts made for Ascarid and Non-Ascarid Eggs Per Gram of Feces									
	8-28-46	9-5-46	9-18-46	10-3-46		10-9-46		10-16-46		10-23-46		10-31-46	
	No. of eggs	No. of eggs	No. of eggs	Asc.	Non-Asc.	Asc.	Non-Asc.	Asc.	Non-Asc.	Asc.	Non-Asc.	Asc.	Non-Asc.
863	117.0	34.4	35.0	46.0	26.0	29.5	5.0	29.0	5.0	51.5	7.5	52.5	5.5
991	130.0	21.0	139.0	...	218.5	...	157.0	1.5	122.5	1.0	120.5	1.0	64.0
883	124.0	74.0	12.0	9.5	12.0	2.5	9.0	1.0	2.5	3.0	4.0	8.5	9.5
908	126.0	69.0	118.0	1.5	4.5	9.0	6.5	11.5	3.0	6.0	1.5	11.0	1.5
903	131.0	175.5	194.0	1.0	84.0	64.5	27.0	67.0	28.0	59.0	13.0	73.0	9.0
935	268.0	115.0	63.0	...	8.0	...	4.5	1.0	1.5	0.5	1.0	...	2.0
960	126.0	83.0	78.5	19.0	14.5	36.5	23.0	25.5	18.5	37.0	12.5	48.0	22.5
979	126.0	115.0	75.0	3.5	45.5	20.5	18.0	15.0	12.5	9.0	19.0	4.0	5.5
984	164.0	83.0	55.0	8.5	43.0	9.0	37.0	6.0	26.5	13.5	34.5	7.5	13.5
941 Died	...	...	...	...	...	...	...	...	...	...	...	...	...
Total	1,315.0	769.9	769.5	89.0	456.0	171.5	287.0	157.5	220.0	180.5	213.5	205.5	133.0

[1] All egg counts should be multiplied by 100.

TABLE NO. 2

NUMBERS OF ASCARID AND NON-ASCARID EGGS PER GRAM OF FECES IN THE PHENOTHIAZINE-TREATED GROUP OF TRIAL I (GROUP B)[1]

Pig No.	Total of Eggs Per Gram of Feces[2]			Differential Counts made for Ascarid and Non-Ascarid Eggs per Gram of Feces									
	8-28-46[3]	9-5-46	9-18-46[3]	10-3-46		10-9-46[3]		10-16-46		10-23-46		10-31-46[3]	
	No. of Eggs	No. of Eggs	No. of Eggs	Asc.	Non-Asc.	Asc.	Non-Asc.	Asc.	Non-Asc.	Asc.	Non-Asc.	Asc.	Non-Asc.
864	181.0	110.0	24.5	4.5	4.5	8.0	1.5	7.0	....	7.0	1.5	0.5	2.5
877	46.0	28.5	16.0	......	36.5	0.5	6.5	0.5	6.5	...	9.0	......	6.5
886	41.0	26.0	51.5	30.0	48.5	28.5	17.0	26.5	13.0	20.5	10.0	10.5	13.0
912	135.0	33.0	17.5	...	7.0	...	3.5	......	5.0	.....	10.0	......	2.0
905	98.0	102.5	88.5	39.5	46.0	0.5	20.5	..	6.5	.....	4.0	.....	3.0
940	381.0	170.5	86.0	3.5	21.0	......	18.0	0.5	6.0	....	7.5	...	5.5
961	226.0	223.5	73.0	36.0	26.0	36.5	18.5	43.0	21.5	24.0	18.0	51.0	33.0
980	55.0	73.0	65.0	......	225.5	....	130.0	1.5	36.5	8.5	78.0	10.5	97.0
986	93.0	65.5	158.5	9.5	59.5	23.0	70.5	16.0	40.5	8.5	30.0	14.0	34.0
994	126.0	96.5	96.0	17.5	80.5	13.5	36.5	14.5	83.5	8.5	60.0	19.0	89.5
Total	1,382.0	929.0	676.5	140.5	555.0	110.5	322.5	109.5	219.0	77.0	226.0	105.5	286.0

[1] All eggs counts should be multiplied by 100.
[2] Differential counts not made for number of ascarid and non-ascarid eggs.
[3] Treatment given three days previous to date indicated.

TABLE No. 3

NUMBER OF ASCARID AND NON-ASCARID EGGS PER GRAM OF FECES IN THE SODIUM-FLUORIDE-TREATED GROUP OF TRIAL I (GROUP C)[1]

Pig No.	Total Eggs Per Gram of Feces[2]			Differential Counts made for Ascarid and Non-Ascarid Eggs Per Gram of Feces									
	8-28-46[3]	9-5-46	9-18-46[3]	10-3-46		10-9-46[3]		10-16-46		10-23-46		10-31-46[3]	
	No. of Eggs	No. of Eggs	No. of Eggs	Asc.	Non-Asc.	Asc.	Non-Asc.	Asc.	Non-Asc.	Asc.	Non-Asc.	Asc.	Non-Asc.
865	187.0	170.0	81.5		65.0		56.0		26.5	0.5	15.5	1.0	4.0
881	70.0	43.5	11.5		30.5		9.0		12.0		10.0		4.5
907	105.0	51.5	48.5		27.0	0.5	16.0		3.0		3.0		1.0
899	405.0	400.0	45.0	1.0	167.0	0.5	14.5		10.5		6.0	0.5	12.0
932	75.0	48.0	32.5		23.5		20.5	0.5	14.5		5.5		5.0
957	255.0	69.5	10.5		12.5		10.0		14.5		26.0		22.0
977	82.0	51.0	173.0		77.0		38.0	1.0	23.0		42.0	0.5	31.0
983	85.0	33.0	45.5		35.0		43.0		18.0		20.5		8.0
990	261.0	169.5	23.5		12.5		11.0		4.5		2.5		4.0
876	125.0	19.0	25.5	1.0	5.5		7.5		5.0		3.0		2.5
Total	1,653.0	1,035.0	497.0	2.0	455.5	1.0	225.5	1.5	131.5	0.5	134.0	2.0	94.0

[1] All eggs counts should be multiplied by 100.
[2] Differential counts not made for number of ascarid and non-ascarid eggs.
[3] Treatment given three days previous to date indicated.

TABLE No. 4

NUMBER OF ASCARIS WORMS FOUND IN THE SMALL INTESTINE UPON POSTMORTEM EXAMINATION

Trial I						Trial 2					
Group A (Control)		Group B (Phenothiazine)		Group C (Sodium Fluoride)		Group D (Control)			Group E (Sodium Fluoride)		
Pig No.	No. of asc.	Pig No.	No. of asc.	Pig No.	No. of asc.	Pig. No.	Female asc.	Male asc.	Pig. No.	Female asc.	Male asc.
863	24	864		865		323	1		321		
883	1	886	3	881		331	1		333		
908	3	912		899		344			341		
903	33	986		983		360	6	3	362		
984	2	980	10	997		384	1	1	381		
935		940		932		385			383		
979	1	877		957		329			320		
				990		335	4		337		
						340	1		349		
						367[1]	3	3	369		
Total	64		13			Total	17	7			

[1] Found with small amount of fibrosis in gastric lobe of liver.

TABLE No. 5

NUMBER OF ASCARID AND NON ASCARID EGGS PER GRAM OF FECES IN THE CONTROL GROUP OF TRIAL II (GROUP D)[1]

Pig No.	Before 1st Treatment 10-8-47 Asc.	Before 1st Treatment 10-8-47 Non-asc.	Treatment period 10-15-47 Asc.	10-15-47 Non-asc.	10-22-47 Asc.	10-22-47 Non-asc.	10-29-47 Asc.	10-29-47 Non-asc.	11-12-47 Asc.	11-12-47 Non-asc.	11-19-47 Asc.	11-19-47 Non-asc.
323....	29.0	15.5	18.0	2.5	13.0	14.0	7.0	32.5	39.0	7.5	17.0	13.5
331....	21.5	26.0	20.5	27.5	11.0	13.5	20.5	17.5	17.0	35.5	19.0	53.0
344....	.....	4.5	.....	3.5	.....	9.0	.....	7.0	0.5	19.0	1.5	26.0
360....	4.0	13.5	3.5	0.5	6.0	36.5	5.5	21.0	26.0	55.0	31.0	11.0
384....	1.0	17.5	0.5	3.5	3.5	16.5	12.0	19.5	13.0	37.0	6.0	19.0
385....	.....	141.0	.....	7.0	.....	51.5	.....	10.0	.....	6.0	0.5	7.0
329....	.....	3.0	.....	0.5	.....	2.5	0.5	6.0	.....	5.0		.....
335....	20.5	15.5	6.0	2.5	9.5	34.0	10.5	11.5	31.0	33.5	25.0	32.5
340....	.....	22.0	.....	.....	0.5	15.5		11.5		11.5	.....	2.5
365....	87.5	10.5	79.0	0.5	69.5	6.0	37.0	1.5	62.0	4.0	46.0	19.0
Tot...	163.5	269.0	127.5	48.0	113.0	199.0	93.0	138.0	188.5	214.0	146.0	183.5

Pig No.	Treatment period 11-26-47 Asc.	11-26-47 Non-asc.	12-3-47 Asc.	12-3-47 Non-asc.	12-10-47 Asc.	12-10-47 Non-asc.	12-17-47 Asc.	12-17-47 Non-asc.	12-24-47 Asc.	12-24-47 Non-asc.	12-31-47 Asc.	12-31-47 Non-asc.	1-14-48 Asc.	1-14-48 Non-asc.
323....	62.0	27.5	50.5	13.5	69.0	19.5	52.5	12.5	38.5	8.0	1.5	7.0	2.5	3.5
331....	27.0	31.0	21.0	25.0	21.0	24.5	20.0	21.5	18.0	23.0	7.0	13.0	8.5	15.5
344....		12.5	.....	0.5	.....	3.5	.....	3.0	.....	0.5	.....	0.5	.....	10.5
360....	57.0	42.5	29.0	2.0	44.0	25.5	38.0	17.0	35.5	8.0	67.5	7.5	40.0	3.0
384....	18.0	40.5	10.0	7.5	13.0	20.5	21.0	39.0	20.5	28.5	17.0	4.0	9.0	5.0
385....		9.0		4.0		13.0		6.0	0.5	7.0	.....	2.5	.....	7.0
329....		2.5	2.0	1.5		8.0	1.0	1.0	.....	2.5	0.5	2.0	.....	2.5
335....	37.0	42.0	28.0	15.5	22.0	9.0	32.5	13.5	27.0	6.5	5.0	4.5	12.5	15.0
340....		23.0	0.5	5.5		7.5	1.5	22.5	3.5	8.5	1.5	1.0	4.0	12.5
365....	84.0	13.5	44.0	3.0	57.5	31.5	55.5	11.5	60.5	12.5	66.0	16.0	45.0	15.5
Tot...	285.0	244.0	185.0	78.0	226.5	162.5	222.0	147.5	201.5	105.0	166.0	58.0	121.5	90.0

[1] All egg counts should be multiplied by 100.

TABLE No. 6

NUMBER OF ASCARID AND NON-ASCARID EGGS PER GRAM OF FECES IN THE SODIUM FLUORIDE TREATED GROUP OF TRIAL II (GROUP E)[1]

Pig No.	Before 1st Treatment		Treatment period																							
	10-8-47		10-15-47[2]		10-22-47		10-29-47		11-12-47[2]		11-19-47		11-26-47		12-3-47		12-10-47[2]		12-17-47		12-24-47		12-31-47		1-14-48[2]	
	Asc.	Non-asc.	Asc.	Non-asc.	Asc.	Non-asc.	Asc.	Non-asc.	Asc.	Non-asc.	Asc.	Non-asc.	Asc.	Non-asc.	Asc.	Non-asc.	Asc.	Non-asc.	Asc.	Non-asc.	Asc.	Non-asc.	Asc.	Non-asc.	Asc.	Non-asc.
321....	30.5	35.5	1.0	8.5	2.0	33.5	4.5	5.5	....	61.0	....	72.0	....	23.0	....	3.5	0.5	8.5	....	10.0	....	8.5	....	7.0	....	2.5
333....	5.0	5.5	....	3.5	....	6.5	....	10.0	1.5	23.0	....	23.5	0.5	22.5	....	8.0	0.5	19.0	0.5	11.0	....	16.5	....	12.0	....	17.0
341....	3.0	1.0	....	5.5	....	3.5	....	1.0	....	8.0	....	5.0	....	10.5	....	8.5	....	5.0	....	3.5	....	5.0	....	1.0	0.5	13.5
362....	16.5	24.0	....	6.0	....	12.0	0.5	11.0	0.5	25.0	1.0	18.5	....	18.5	1.0	8.5	....	32.5	1.0	19.0	0.5	18.5	....	10.0	....	11.0
381....	....	23.5	....	7.5	....	16.0	....	15.5	1.0	24.0	....	25.0	....	12.5	0.5	15.0	....	8.5	....	11.0	....	9.5	....	12.5	....	19.0
386....	1.0	24.0	....	19.0	....	41.0	....	61.0	0.5	55.5	....	6.5	0.5	25.0	....	9.0	....	23.5	0.5	6.5	....	11.0	....	8.5	....	11.0
320....	8.5	7.5	....	3.5	....	3.0	....	2.5	....	13.0	....	6.5	....	6.0	0.5	1.5	....	3.0	0.5	8.5	0.5	5.5	0.5	7.5	....	6.0
337....	75.5	8.0	4.0	5.5	....	1.5	....	3.0	....	13.5	0.5	6.0	....	2.5	0.5	1.5	....	5.5	0.5	2.5	....	5.0	....	7.5	....	2.5
349....	....	30.0	....	15.0	....	15.0	....	12.5	....	20.0	....	12.0	....	5.0	....	2.5	....	5.0	....	6.5	....	2.0	....	5.0	....	5.0
369....	26.5	7.5	....	1.0	....	8.5	....	9.5	1.0	18.5	....	2.5	....	17.0	1.0	11.0	1.0	17.5	1.5	10.5	2.0	17.5	2.2	5.0	....	5.5
Tot...	166.5	166.5	5.0	75.0	2.0	140.5	5.0	131.5	4.5	261.5	1.5	177.5	1.0	142.5	3.5	69.0	2.0	128.0	4.5	89.0	3.0	99.0	2.7	76.0	0.5	92.5

[1] All egg counts should be multiplied by 100.
[2] Treatment given three days previous to date indicated.

Prior to the first treatment with sodium fluoride, there were no statistically significant difference in either ascarid or non-ascarid egg counts between groups "D" and "E". The data for total ascarid eggs from the time treatments were started to the end of the experiment, exhibited a highly significant difference between the sodium-fluoride-treated and the control pigs (tables 5 and 6). On the other hand, the data for total non-ascarid eggs of the sodium-fluoride-treated and control groups collected during the same period (treatment period) showed no statistically significant difference between the two groups.

Upon slaughter, the small intestines of the sodium-fluoride-treated animals (group "E") were found free of ascarid worms, while seven of the ten control pigs (group "D") were infested with a total of 24 ascarides (table 4). All viscerae (groups "E" and "D") were found normal except one pig in group "D" (pig No. 365) which had a small amount of fibrosis in the gastric lobe of the liver. This pig, as will be noticed from table 5, shed the highest number of ascarid eggs throughout the experimental period.

Data were also collected for the growth rate of the two groups studied in this second trial. The growth rates were similar to those obtained in Trial I. The difference in the rate of gain between groups "D" and "E" was statistically non-significant.

Discussion

The results obtained demonstrate that the pigs given sodium fluoride were apparently free of ascarides for the duration of the trials as ascertained by differential egg counts. Upon slaughter, they were found to be free of ascarides. The ascarid eggs found in the feces of some treated animals were nonembryonated eggs and were probably eggs that were engulfed in the noninfective stage.

Phenothiazine did not exhibit satisfactory ascaricidal properties as shown by the egg counts of table 2 and the recovery of adult worms from the small intestines as shown in table 4. Phenothiazine, in the concentration used, did not prevent infection as shown by pig No. 980 (table 2) which, although free of ascarid eggs on October 3 and October 9, indicated an increasing amount of eggs shed up to the end of the trial and which was found to have ten adult worms when slaughtered.

In addition, a study of the data of table 2 indicates that the phenothiazine did not consistenly lower the number of ascarid eggs.

The data secured in this study indicate that sodium fluoride is a more satisfactory ascaricide than phenothiazine, at the dosage used. The sodium fluoride proved effective after one treatment. This was shown by the data collected for the number of ascarid eggs shed before and after the first treatment (see ascarid egg counts on October 8 and October 15, 1947 in table 6). No injurious or toxic effects treatment (see ascarid egg counts on October 8 and October 15, 1947 in table 6). No injurious or toxic effects were noted when the use of the one-per-cent mixture with the feed was given every 3 or 4 weeks for periods of 3 to 4 months. Weight gains were not affected by the drug treatments: the control and the sodium-fluoride-treated pigs made similar weight gains. Sustained use of the drug kept the pigs free of adult worms. This is of invaluable advantage where lots are heavily infested and poor management practices prevail. First, there will be fewer adult parasites living at the expense of the feed provided for the growing pigs and secondly, there will be a progressive decrease of chances of infection as a result of having progressively fewer fertile eggs deposited upon the ground.

In relation to the parasitic organisms present, sodium fluoride seemed to be a specific for ascarides. No differential counts were made for non-ascarid eggs but the following types were the most commonly found: *Strongyloides*, *Oesophagostomum*, *Hyostrongylus*, *Globocephalus* and *Trichuris*. As the number of these eggs did not decrease as the result of treatment, the sodium fluoride presumably had little or no effect on those organisms.

It may also be stated that in addition to being a reliable ascaricide, sodium fluoride is very economical to use and easy to administer. The mixture of feed and sodium fluoride was found to be palatable.

Summary and Conclusions

Two trials were conducted to test the value of sodium fluoride as an ascaricide for growing pigs kept on infested grounds. The ability of the drug to kep animals free from ascarides and the possible toxicity upon repeated treatment were also studied.

Three groups of animals similar as to breeding, weight and age were used in Trial I. Group "A" served as control. Group

"B" received 0.2 gm. of phenothiazine per pound or bodily weight and group "C" one per cent sodium fluoride mixed with ground feed. Except for slight variations in the procedure and the elimination of the phenothiazine treatment, Trial II was conducted in the same manner.

The effectiveness of the different treatments given during the experimental period was measured by statistical analyses of the number of ascarid and non-ascarid eggs per gram of fresh rectal feces secured once every week, by the weight gains made by each animal, and by the number of *Ascaris* worms found upon visceral examination.

The results obtained suggest that sodium fluoride at the rate of one per cent mixed in the feed every three weeks is a very satisfactory drug for killing *Ascaris lumbricoides suis* found in growing pigs raised on the ground. When fed repeatedly to growing pigs for periods of from 3 to 4 months it was effective in keeping the animals clean, with no toxic effects whatsoever.

Phenothiazine at the rate of 0.2 gm. per pound of bodily weight administered every three weeks was found to be unreliable as an ascaricide.

The data obtained during the two trials made suggest that sodium fluoride is specific against *Ascaris lumbricoides suis.*

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THE USE OF CANE MOLASSES AS PART OF THE CONCENTRATE DAIRY RATION USING MERKER GRASS AS ROUGHAGE

By

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INTRODUCTION

"Only that dairyman can succeed who feeds his cows both economically and efficiently".[6]

Intensive milk production in Puerto Rico is generally dependent upon concentrate feedstuffs. Most of these feedstuffs are imported from the United States at prices which represent more than 50 per cent of the cost of milk production. The total value of dairy feeds imported to the Island during 1945–1946 [2] was almost four million dollars.

During 1945–1946, Puerto Rico produced around 38.5 million gallons of molasses. Of this, a large amount was used by the rum industry or exported, and very little was used as livestock feed.

In the United States, molasses is added to high-grade mixed feeds on account of its palatability, and also because it is one of the cheapest of readily digestible carbohydrates.[14] In the past, feeds containing molasses were imported to the Island and dairymen were paying an excessive price for the molasses put into the feed. Due to the fact that in tropical climates molasses undergoes fermentation under prolonged storage, the importation of molasses-containing feeds was discontinued.

As Puerto Rico is a sugar-cane growing country, molasses should be an economical substitute for part of the grain in feeding dairy cows and other livestock on the Island.

LITERATURE REVIEW

Ellison and Varas Catala,[7] in Puerto Rico, supplemented the grain ration of one group of cows with cane molasses and of another group with corn chops,* and used cane as the only

* Corn chops- corn and cob chopped.

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roughage. The chopped-corn lot consumed more feed and produced more milk, but the greater economy in cost of milk production resulted when the molasses was added to the ration. Labh Singh and Sahi Gambhir [12] found that for feeding bullocks in India molasses could replace corn pound for pound.

McComas et al.[13] said that on the basis of average data for four experiments using Herford steers in terms of live-weight produced, the corn-molasses mixture in the ratio of 1 to 1 was approximately 80 per cent as efficient as corn, whereas the mixture in the ratio of 3 to 1 was approximately 90 per cent as efficient. Britnal [6] feeding dairy cattle in Mississippi, stated that, practically one pound of molasses was equal to one pound of corn. Morrison [14] cites two Wisconsin experiments where 10 per cent of cane molasses was incorporated into a mixture of palatable concentrates; the milk production was practically the same as on the concentrate mixture without molasses. In these trials, the molasses was worth 89 per cent as much per pound as ground corn.

Bary et al.[5] found, for fattening steers, that molasses had a calculated value of 85 per cent that of corn. In individual tests, the value ranged from around 85 per cent up to better than 100 per cent of the value of corn. Their experiments indicated that molasses was used most efficiently when fed at around 3 to 4 pounds per head daily.

Experimental studies and practical experience with dairy cattle at the Missouri Station [1] showed that molasses may satisfactorily replace $^1/_4$ to $^1/_3$ of the ground corn. Usually not more than two to three pounds of molasses should be fed daily per 1000 pounds of live weight.

Skinner and King,[17] feeding cattle in Indiana, came to the conclusion that the advantage of feeding molasses arose from its low cost rather than from the feeding value. The nutritive value of molasses was slightly lower than an equal weight of corn as measured by the rate of gain and finish of the cattle.

Snell et al. [18] at Louisiana, found that molasses was equivalent to corn grain as a feed for working mules. Their early experiments indicated that molasses is only slightly less valuable than corn pound for pound as a feed for dairy cattle.

It was found in Hawaii, in experiments conducted by Henke [10] covering a period of seven years, that when properly supplemented with protein-rich feeds, cane molasses could be satisfactorily substituted for one quarter of the concentrate usually

fed dairy cows. The use of molasses did not affect the reproductive efficiency or increase abortions. Henke emphasizes the importance of using more molasses in the dairy rations due principally to differences in price. Willet et al.,[19] in another series of trials in Hawaii, stated that pigs, from time of weaning until they reach a weight of 60 to 70 pounds, can utilize cane molasses effectively up to levels of 20 per cent of the ration. There was no appreciable difference in the amount of total digestible nutrients required per pound of gain. The data indicate that molasses is equal to barley when fed at these levels and when compared on total-digestible-nutrient basis. The feed cost per pound of gain decreased with the increase in the amount of molasses fed. When molasses was fed at levels of 30 to 40 per cent of the rations, the rate of gain and efficiency in the utilization of feed or the total digestible nutrients decreased markedly. The accompanying diarrhea was another factor that affected the utilization of the high molasses rations.

Ott et al.[15] used molasses in poultry rations and stated that the use of molasses up to six per cent in the rations substituting corn depends upon the prices of both corn and molasses. Brigs et al.[3] working with lambs said that the results of a limited amount of work on the tolerance of lambs for blackstrap molasses indicated that lambs can utilize the product at a level of 10 per cent of the ration more efficiently that at a level of 25 per cent. They [4] noted that in two digestion trials in which eight lambs were used, substitution of blackstrap molasses for at least one half of the corn in a lamb-fattening ration lowered the coefficient of apparent digestibility for protein, fat and nitrogen-free extract in appreciable amounts. On the other hand, Williams [20] said that the data of his experiments indicated that the digestibility of the crude fiber, the nitrogen-free extract, and the ether extract was not uniformly affected in either direction by the presence of molasses in the ration. He agrees with Brigs and Heller [3] in the fact that molasses tends to depress the digestibility of crude protein and dry matter; however, he adds that this depression is so slight that it would scarcely be appreciable in ordinary feeding practices.

Kraus [11] at Ohio, found that cane molasses as a supplement to milk for rats produced excellent growth, prevented nutritional anemia, and was of value for haemoglobin regeneration in anemia. Beet molasses did not prevent anemia and had no beneficial effects on rats suffering from nutritional anemia. Chemical

analyses showed that cane molasses contained larger quantities of iron and copper than did beet molasses.

Molasses seems, therefore, to have a well-defined position as a feed for livestock. Its value has been compared with corn in many different experiments. In conclusion, it can be said that its value ranges from 80 to 100 per cent of the value of corn or other carbohydrate feed and the variation depends on the proportion which is used in the mixture. For dairy cows care should be taken to maintain the protein content of the mixture at an adequate level to prevent harmful effects on milk production.

EXPERIMENTAL

Eighteen cows divided in three groups of six each were used in the experiment. The groups were balanced according to the stage of lactation period and milk production. All the cows were giving over eight pounds of milk daily and none was over ten months in lactation. Except for four purebred Holstein cows, all cows were Holstein-Native crossbreds with varying amounts of Holstein blood.

The experiment consisted of a single reversal trial using the groups as follows: After a five day pre-feeding period, the first group was fed regular Merker grass and regular 20 per cent protein concentrate ration at a level of 1 pound of concentrate for every 2.0 pounds of milk. A narrow ratio of feed to milk was used to compensate for the lower quality of the roughage. The second group was fed the same kind of grass but the concentrate ration consisted of four parts of regular 20 per cent protein concentrate feed and one part of cane molasses. The third group was fed young Merker grass plus the molasses-concentrate ration. The first part of the experiment lasted for 18 days, pre-feeding excluded.

For the second part of the experiment, the first two groups were switched on the concentrate rations. The third was fed the regular mature Merker grass pus the molasses-concentrate ration. The second part of the experiment lasted for 17 days, pre-feeding excluded.

The cows were weighed for three consecutive days at the beginning of the experiment, at the end of the first part and at the end of the second part of the experiment. Roughage consumption and milk records were kept daily for each individual cow. Forage samples for moisture content were gathered twice a week. These samples were dried in an oven at 70°C.

The molasses was mixed with the feed by spreading the feed on a concrete floor and sprinkling the molasses over it as evenly as possible. Two men with shovels mixed the concentrate feed and molasses thoroughly. The mixing was done this way due to the fact that the majority of the dairies in the Island do not have mixers to mix the ingredients. Enough feed was mixed every time for two or three days.

The milk production of the animals in the different groups depended on a number of factors, among which the ration fed, the stage of lactation, and individual differences between the animals may be mentioned. In order to determine the effects of the differences in the rations fed on the milk production of the different groups, a regression equation was adapted to the milk production figures. The equation constants represent the differences in milk production due to differences between the rations fed and to the effect of the stage of lactation.

Fitting of the regression equation and calculation of the standard error of the constants were made according to the methods described by Snedecor.[16] Difference in roughage consumption as well as weight differences were also studied.

Results

Milk production for the experimental periods is presented in table 1. Pre-feeding periods were excluded.

Table No. 1

MILK PRODUCTION IN POUNDS FOR ALL ANIMALS DURING THE EXPERIMENTAL PERIODS*

Name of Cow	Ration No. 1	Ration No. 2	Ration No. 3
	Second Period	First Period	
Vera	149 2	176.9	....
Nana	93.6	151.2	....
Lupe	368.2	395.9	....
Carmelita	321.1	325.8	....
	First Period	Second Period	
Laura	184 7	192.8	....
Soroca	502.0	493.0	....
Walker	287 0	158.3	....
Nellie	322.2	285.9	....
Rivera	376.6	366.9	....
		Second Period	First Period
Toledo	....	164 0	192.7
Mulata	....	82.2	121.8
Dunure Jr.	....	264.4	305.0
Luisa	....	283.8	362.3
María	....	286.9	343.1
Coamo	....	214.3	372.6

* Three cows were not able to finish in the experiment due to sickness; they were not included in the comparisons.
Ration No. 1—cows on regular Merker grass and concentrate alone.
Ration No. 2—cows on regular Merker grass and molasses-concentrate.
Ration No. 3—cows on young Merker grass and molasses-concentrate.

The constants of the fitted equation and their respective standard errors are as follows:

	Constants	S. E.	Meaning of Constants
A	7.65	15.38	Difference in production due to rations 2–1
B	–36.26	24.31	Difference in production due to rations 1–3
C	32.27	15.38	Difference in production due to periods 1–2

The above constants are subject to twelve degrees of freedom and none of them is, therefore, significant. Thus, the evidence available does not indicate any superiority of the 100 per cent concentrate feed as against 80 per cent concentrate feed and 20 per cent molasses or vice versa.

Molasses did not have any significant depressive effect on milk production when used as a substitute of the concentrate ration to the extent of 20 per cent. On the other hand the molasses has definite advantages that will be discussed later on.

TABLE NO. 2

SUMMARY OF ROUGHAGE CONSUMPTION BY GROUPS

No. of cows	Ave. wgt. pounds	Average pounds consumed	Average per cent dry matter	Average D. M.[1] consumed daily	D. M. per[2] 100 pounds L. W.[3]	Ave. wgt. pounds	Average pounds consumed	Average per cent dry matter	Average D. M. consumed daily	D. M. per 100 pounds L. W.[3]
	First Period					Second Period				
	Regular Merker grass molasses-concentrate					Regular Merker grass no-molasses concentrate				
4	941	1,276.00	28 00	20.00	2.13	917	1,299.00	28.00	21.00	2.36
	Regular Merker grass no molasses concentrate					Regular Merker grass molasses concentrate				
5	1,033	1,171.00	28.00	18 00	1.78	1,012	1,280.00	28 00	21.00	2.11
	Young Merker grass molasses concentrate					Regular Merker grass no molasses concentrate				
6	891	1,445 00	25 00	20 00	2.26	878	1,203 00	28 00	20.00	2.28

[1] D. M. dry matter.
[2] L. W. live weight.
[3] In checking, results may not agree with data due to the fact that figures were rounded in the table.

Although this was a short time experiment, the results were similar to those obtained by Henke [10] in Hawaii, in a seven-year period, and by other workers.

The average amount of roughage consumed during the experimental periods by each group of cows is presented in table 2.

Except in the case of the second group in the first experimental period, the average dry matter consumed per 100 pounds of live weight during the course of the experiment showed very little difference, indicating a more or less equal intake of nutrients from the roughage. When the data were treated statistically, they showed no significant differences among the groups.

Variations in bodily weight during the experiment are shown in table 3.

TABLE No. 3

WEIGHT LOSSES DURING THE COURSE OF THE EXPERIMENT

Group No.	No. of cows	Average loss in weight by groups, in pounds	Average loss per cows in pounds
1	4	98.00	24.50
2	5	105 00	21.00
3	6	52 00	8 60

As shown by the average weight lost per cow in the 44 days of experiment (pre-feeding periods included) they practically maintained their initial weights throughout. No statistically significant difference was found among the groups.

Discussion

Molasses has been always the cheapest source of carbohydrate food in Puerto Rico. An illustration of this is presented in table 4, where prices for an eleven-year period are compared.

Table No. 4

RETAIL PRICES FOR MOLASSES AND 20 PER CENT PROTEIN DAIRY FEED 1938 TO 1948

Year	Molasses Drums of[1] 54 gallons, 650 lbs.	Price of molasses, per 100 pounds	Price of 20% protein[2] dairy feed, per 100 pounds
1938	$1.62	$0.25	$1.95
1939	1.62	0.25	2.10
1940	2.70	0.42	2.24
1941	2.70	0.42	2.41
1942	5.13	0.79	3.61
1943	2.50	0.38	2.48
1944	6.48	1.00	3.79
1945	7.34	1.13	3.64
1946	7.34	1.13	4.29
1947	8.37	1.29	4.81
1948	12.04	1.85	5.45

[1] Personal communication of the Administrator, Central San José, Rio Piedras, July 1948.
[2] Personal communication of the Manager, Sociedad Agrícola Cooperativa, San Juan, Puerto Rico, July 1948.

A real saving will be attained due to the difference in prices, plus other advantages such as those of adding palatability and flavor to the ration. A simple way of calculating the saving by the use of molasses as 20 per cent of the concentrate ration is as follows.

Actual cost of 100 pounds of 20 per cent total protein dairy feed	$5.50
Actual cost of 100 pounds of molasses	$1.85
Cost of 80 pounds of 20 per cent dairy feed	$4.40
Cost of 20 pounds of molasses	$0.37
Cost of one hundred pounds of the mixture	$4.77

In the above example there will be a saving of 73 cents or 13 per cent of the cost of the feed, due to the use of molasses. The net income will be a little less due to the labor used in the preparation of the mixture. Using 1945–46 figures, which show that the Island imported around four million dollars of concentrate feeds, the savings will amount to one-half million dollars.

At this point of the discussion two questions arise. Does the addition of that amount of molasses appreciably affect the percentage of total protein in the mixture?, and, do the cows get adequate amounts of protein from that mixture for normal milk production? Using molasses at a rate of 20 per cent of the

concentrate feed the percentage of protein in a 20 per cent protein concentrate mixture is lowered, theoretically, to 16 per cent. The results of the experiment indicated that the milk production was normal.

Extensive work conducted at the New York (Cornell) Station [8] has shown that very little difference in milk production is to be expected when feeding concentrates containing 16 per cent and 20 per cent protein at the conventional ratio of one pound of feed to three and one half pounds of milk, using Timothy-clover mixed hay and corn silage. Further studies at Ithaca [9] indicated that a very small increase in milk production could be expected from a 20 per cent total protein concentrate as compared to the 16 per cent total protein concentrate, but this increase in production is not large enough to warrant the purchase of a 20 per cent total protein over a 16 per cent if the cost of the 20 per cent is greater.

Experiments conducted at this Station (J. I. Cabrera, unpublished results) showed no significant difference in production when a 16 per cent total protein mixture was compared to a 20 per cent, using ratios of one pound of feed to two pounds of milk or a ratio of one to three respectively. In a second experiment, 20 and 24 per cent total protein mixtures were better than the 16 per cent. Henke [10] stated that using protein-rich feeds, molasses can be substituted for 25 per cent of the mixture.

These results show that dairymen in Puerto Rico and farmers in general should be using molasses on a larger scale as feed for livestock. Its nutritive value has been known for years, (see literature review). The Island produces a large amount of it most of which is sold abroad, due to a lack of acceptable prices in the local market. If the usage of molasses becomes general throughout the Island, both cane-growers and dairymen will benefit.

Summary and Conclusions

Two groups of cows were fed regular Merker grass soilage, 20 per cent protein concentrate, and a mixture of four parts of a 20 per cent protein concentrate plus one part molasses in a switch-back feeding trial. A third group was fed young Merker grass for the first part of the experiment, and regular Merker grass for the second part, plus the molasses-concentrate ration with each grass.

Statistical analysis of the data indicates that molasses did not have any depressive effect on milk production. The amount of dry matter in roughage consumed per 100 pounds of live weight was essentially the same for all groups; the difference was statistically non-significant. Although body weight was not maintained throughout the experiment, the difference in weight lost among groups was not statistically significant.

Due to the difference in price between molasses and the mixed dairy feeds, the use of molasses can effect considerable saving to the farmer who uses it as part of the concentrate ration. It can be substituted for 20 per cent of the concentrate ration and probably more.

As Puerto Rico is a sugar cane producing area, molasses should be used locally to a greater extent as a livestock feed. It is readily available and is the cheapest source of carbohydrates on the Island.

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A QUINTESSENCE OF SENSITIVITY: THE COFFEE LEAF-MINER

By GEORGE N. WOLCOTT [1]

High humidity, with many rainy days, characterizes the climate of the lower mountainous slopes of tropical America where Arabian coffee, *Coffea arabica* L., grows. Even on sunny days, clouds often drift by overhead, their passing shadows inducing the sudden darting flight of numerous little satiny white moths, the adults of the coffee leaf-miner, *Leucoptera coffeella* Guérin-Méneville. When the sun reappears, flight ceases as suddenly as it began, and the coffee grove that was alive with the flashes of their wings a minute ago now appears deserted of active insect life.

Despite their small size, they are quite conspicuous in flight, but when at rest they closely fold their silvery wings around their body. The sudden, positive manner in which these minute insects react to a variation in light intensity is characteristic of their reactions to other natural factors of their environment.

Humidity is decisive in determining in what parts of the grove heavy leaf-miner infestations will develop, altho to temperatures within the limits at which coffee thrives, the insects appear relatively insensitive. The female moths tend to oviposit mostly on wind-swept ridges where the evaporating power of the wind is greatest, and least at the bottom of ravines where the wind can not penetrate, and relative humidity remains high at all times. Climbing the slope, one finds all gradations in the amount of infestation, with the maximum always where the action of the wind is most marked. Porous-cup atmometers show this in the coffee grove, as does artificial rearing of the insect in separate compartments of a greenhouse of which the humidity can be controlled. There is the very best of reasons why the female moths should prefer the more exposed plants for oviposition, as during prolonged periods of rain the mines of the caterpillars in the coffee leaves become filled with water, in which the caterpillars drown. During such weather, it is

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in the exposed situations that the wind dries out the leaves most rapidly and it is here that the insect will have the best chance for survival. Indeed, it is on the single factor of humidity that most of the observed differences in abundance of leaf-miner depend.

The scarcity of the leaf-miner in Haiti, as compared with its abundance in Puerto Rico, is due to local methods of no cultivation, and allowing coffee trees to grow wherever volunleer plants had happened to sprout, making such a dense tangle of trees that humidity is always high, while soaring mountains often cut off all exposure to winds. New plantings in Haiti, with small trees widely spaced and open to the wind, invariably suffer heavy infestation just as they do in Puerto Rico. The scarcity approaching total absence of coffee leaf-miner in old Haitian groves is definitely not due to some new and more efficient larval parasite, for all collected in Haiti had previously been known from Puerto Rico, and *Chrysocharis lividus* Ashmead, reported by O. W. Barrett as long ago as 1905 and often the most abundant of any in Puerto Rico, does not occur in Haiti at all. Even proper wide spacing of the trees fails to provide a suitable environment for the leaf-miner in Trinidad, which is out of the trade wind and hurricane belt, and its coffee groves have maximum humidity in the ravines in the Northern Range of mountains.

Sensitive as the ovipositing female moth is to differences in humidity, apparently she does not distinguish between Arabian coffee with tender leaves suitable for the development of her young, and such a tough-leaved species as *Coffea stenophylla* Don. The minute caterpillar developing within a leaf-miner egg laid on such a tough leaf hatches normally, and without emerging from the protective covering of its egg-shell, eats thru it directly into the leaf tissue beneath. It attacks the tough leaf tissue with apparent success at first, but often by the second day all activity has ceased, and the little caterpillar is dead. Had the egg been laid on a leaf of Arabian coffee, the minute caterpillar would normally continue eating a cavity into the central tissue of the leaf until this is large enough so that it could crawl entirely out of the egg-shell. Like most kinds of insect larvae living in a protected situation, its flattened body is opalescent whitish, the head somewhat darker, with the sharp edges of its jaws almost black. It continues to eat and increase in size within its mine in the coffee leaf, feeding only

on the most tender cells and avoiding those of both the upper and lower outside skins of the leaf.

Leaf-miner larvae attacking some other kinds of leaves are sometimes precipitated into the outer world during rainy weather, when the thin outer skin of the leaf they have attacked is rotted by rain. Those of even the most tender coffee leaf are of tougher texture and resist decomposition at least long enough for the caterpillar to complete its growth, but unfortunately are sufficiently permeable to rain-water so that it collects in the mine, distending it almost to bursting.

Drowning in its rain-water filled mine is not the only peril besetting the coffee leaf-miner caterpillar in its mine. Numerous kinds of minute parasitic wasps occur in coffee groves, which, with their minute sharp ovipositor, may puncture the skin of the mine and lay their egg on or within the body of the caterpillar. In Puerto Rico, Mr. Francisco Sein has reared ten kinds of these minute wasps which are either parasites or super-parasites on the coffee leaf-miner. Arranged approximately in the order of their abundance, their names, as determined by Mr. A. B. Gahan of the U. S. National Museum, are as follows.

Closterocerus leucopus Ashmead
Chrysocharis livida Ashmead
Horismenus cupreus Ashmead
Zagrammosoma sp. nov.
Closterocerus sp. near *cinctipennis* Ashmead
Cirrospiloideus sp. nov.
Derostenus sp. near *fullawayi* Crawford
Tetrastichus sp. nov.
Telenomus sp.
Microbracon sp. (det. C. F. W. Muesebeck)

In coffee groves near the coast and at no great elevation, some of these minute leaf-miner parasites are at times reasonably abundant, but at the higher elevations where most coffee is produced, they are far from numerous and usually are so scarce that all of them together rarely destroy more than an eighth or a tenth of all leaf-miner caterpillars. From the commercial standpoint, therefore, they are of negligible importance, and even the entomologist finds them so scarce that careful studies of each one, to determine its status and non-parasitic habits, are almost impossible. This list of parasites is longer from Puerto Rico than from the other Larger Antilles

only because studies here have been more intensive, but the same or similar parasites occur in the coffee groves of all of these larger islands.

Quite different is the parasitic situation in the coffee-producing islands of the Lesser Antilles, for Mr. Seín discovered a previously undescribed parasite, later named *Mirax insularis* by C. F. W. Muesebeck, to be normally responsible for the destruction of sixty to eighty-five percent of all leaf-miner caterpillars in the island of Guadeloupe, F. W. I., and only slightly less effective in other adjacent islands. Introduced into Puerto Rico in 1937, it is unquestionably established in the mountains around Lares, but even when present in greatest abundance, attacks less than three percent of the leaf-miner caterpillars, and at most times only a small fraction of one percent will be found parasitized by *Mirax*. The desirability is obvious of the most careful comparative ecological study of the requirements of each and every parasite of the coffee leaf-miner in every island of the West Indies. The establishment in coffee groves of the optimum conditions for the development of some or most of these parasites may be impossible of practical attainment, but the factor lacking for one or several may be readily supplied, if we know what that factor is, and thus result in commercial leaf-miner control.

When fully-grown, the leaf-miner caterpillar is less than a quarter of an inch in length, smaller indeed than many other kinds of caterpillars just hatched from the egg. It acts like some of them also, in a most interesting way, for emerging from its mine when the wind is not blowing, it spins a long thread of silk with incredible swiftness as soon as a breeze begins to blow. If the breeze stiffens, the thread soon becomes so long as to be buoyant to the insignificant weight of the caterpillar, so that as soon as the thread breaks loose from attachment, the caterpillar may be carried far from the leaf from which it obtained its nourishment. This phenomenon can be most readily observed during a period of fitful breezes: the dropping of the caterpillars on their threads as soon as the breeze starts, and sudden halt when the breeze stops, followed by a prompt lengthening of the threads again as the breeze starts. If the breeze stops entirely, the caterpillar is left indefinitely suspended in mid-air, a ready prey to any passing reinita or warbler.

Spinning of the cocoons may take place on any leaf, not necessarily of coffee, but of any plant that happens to be present in the grove. In the selection of a position for the cocoon, the caterpillar is sensitive to varying intensities of light, for in complete shade the cocoon may be formed on the upperside of a leaf. Normally, however, it is on the underside, the caterpillar first constructing a silken hammock under a slightly raised portion of the leaf, this support of white silk often taking the form of an X. Upon this silken mattress the caterpillar spins the cocoon proper, within which it transforms to pupa. It remains as pupa three to nine days. The moth leaves the cocoon at night, mates, and often has completed oviposition by the next day.

Within the short span of its life-history, the leaf-miner both as adult and as caterpillar has shown itself very sensitive to variations in light intensity; as adult to humidity, and as caterpillar to air in motion. When as much is known about the reactions of each of the parasites of the leaf-miner to natural conditions in coffee groves as is known of their host, we may anticipate much more efficient natural control of this pest of coffee by its parasites.

January 8, 1943.

Footnote:

This summary of observations on the coffee leaf-miner made with and by Mr. Francisco Seín Jr., is published at the present time because of his departure from the Experiment Station, effective June 30, 1948, after continuous employment there since October 8, 1918. The original publication of most of these observations is scattered thru the reports of the Division of Entomology in the Annual Reports of the Experiment Station from shortly after that date almost up to the present.

GEORGE N. WOLCOTT.

THE LEAFHOPPERS OF WHITE CLOVER, *Trifolium repens* L., IN NORTHERN NEW YORK AND IN THE MOUNTAINS OF HAITI

By George N. Wolcott [1]

A bountiful and never-failing spring of clear, sparkling water flowing out of the mountainside is largely responsible for the intensive agricultural development of the region around Kenscoff, Haiti. The abundance of water makes possible the production of such crops as watercress just below the springs, and of lettuce, onions, cabbage, potatoes, carrots and other temperate zone vegetables by irrigation at somewhat lower levels, and more especially of artichokes. Peach trees thrive at an elevation of around 4,000 feet, now producing an abundance of fruit since the apparently perfect natural control of the West Indian peach scale, *Pseudalacaspis pentagona* (Targioni), resulting from the introduction of the twice-stabbed ladybeetle, *Chilocorus cacti* L. The effectiveness of this ladybeetle, endemic in Texas and Cuba, whence it was brought to Puerto Rico and then sent to Hispaniola, is seriously lessened at lower elevations in the tropics by the abundance of predaceous lizards, but these are notably scarce so high in the mountains. Indeed, both flora and fauna are primarily temperate zone, the original forest being replaced by the first European settlers with the plants with which they were familiar in France, not only fruits and vegetables, but also the same grasses and clovers, and not excepting the weeds. The pastures of the steeper slopes not in irrigation to a large extent are composed of white clover, furnishing a rich forage for cows whose milk is the basis for a small butter and cheese industry.

Sweeping areas in white clover (*Trifolium repens* L.) mixed with European grasses in a field where sweet-peas had been grown for export last year, the largest, most abundant and by far the most conspicuous leafhopper present on the clover on February 1, 1948, was found to be *Hortensia similis* (Walker). Originally described from Central America as a *Tettigonia*, and for many years called a *Kolla*, this common neotropical leaf-

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hopper, opaquely light green above, with a distinctive and unvarying pattern in black on head and pronotum, was possibly most intensively studied at the time when mosaic disease of sugar-cane was invading Puerto Rico, for it seemed to be the most probable vector of the disease.(1) In fields of young cane, its abundance varies directly with rainfall. During drought, the adults retreat to moist meadows of "malojillo" or Pará grass (*Eriochloa subglabra* and *Panicum barbinode*), to stream margins, or to the grasses of mountain pastures and the margins of forest and coffee groves. Nymphs have been reared on young sugar-cane plants, and occur in abundance on grasses, but rarely are found on corn, beans, carrots and weeds, from which adults have been swept. The nymphs "feed nearly half the time. With their thick beak inserted in the cane plant, they let go with their legs, using them to get rid of the minute drop of colorless excreta which collects at the anus. With all their legs in motion at once and these little drops of moisture being hurled into the air at the rate of one every seven seconds, a colony of *Kolla similis* nymphs feeding is a most exciting spectacle." Among the numerous adults swept from white clover at Kenscoff were a few nymphs, which may of course have been feeding on the grass interspersed with the clover and not on the clover itself. It is hardly possible, however, that the numerous adults could have confined their feeding to the scanty grasses present in the dominantly white clover areas, and clover may be considered as a normal host for this leafhopper at the higher elevations in the tropics where clover can maintain itself.

Of the other less numerous, less conspicuous and much smaller leafhoppers swept from white clover at Kenscoff, Dr. John S. Caldwell identified and listed in order of abundance *Unerus colonus* (Uhler), previously known on carpet grass (*Axonopus compressus*) in mountain pastures in Puerto Rico; *Deltocephalus sonorus* Ball, abundant on malojillo; *Nesosteles incisa* (Matsumara) on seed-heads of malojillo; the cosmopolitan *Exitianus obscurinervis* (Stal), and a few individuals of the light green *Empoasca sativae* Poos and *Empoasca dilitara* Davidson and DeLong. Most of these are neotropical or West Indian leafhoppers, and that they should occur on white clover in tropical Haiti would appear to indicate its introduction from France, presumably as seed, without any of its specific leafhopper pests.

The completeness with which white clover may occupy the environments to which it is particularly well adapted, to a considerable extent depends on the specific insect pests attacking it. In a pasture in northern New York, so closely cropped by cows that the recumbent habit of this clover made it the dominant plant, but a single leafhopper, *Agallia quadripunctata* (Provancher), specifically fed upon it.(²) Of this leafhopper, approximately one hundred and fifty were counted in one hundred square feet of pasture; so few that their effect on the host was practically negligible. Much more abundant was what Dr. Herbert Osborn(³) calls the meadow leafhopper. *Acucephalus nervosus* (Schrank), of which approximately five hundred nymphs and adults were present in the same hundred square feet. Bluegrass, redtop, sweet-scented grass and some timothy were present in this pasture, and may have been the normal hosts, but adults were noted resting on white clover, and possibly feeding on it. The other leafhoppers present were the timothy crown leafhopper, *Aphrodes albifrons* (L.), and in smaller numbers: *Leavicephalus affinis* (Gillete & Baker), *Polymia inimica* (Say), *Amblysellus curtisii* (Fitch) and *Balclutha impictus* (Van Duzee), most of which were so scarce as possibly having nothing to do with the white clover. Indeed, its major pests in northern New York were introduced weevils and a cutworm, of which none was noted in Haiti, and from which it may be entirely free in the tropical environment.

The only Fulgorid certainly identified from the white clover pasture in northern New York was *Bruchomorpha occulata* Newman, which was so scarce that no observation on host relationships was possible. In Haiti, Dr. Caldwell identified the most common Delphacid as *Delphacodes propinqua* (Fieber); others were *Delphacodes teapae* (Fowler), *Sogata furcifera* (Horvath) and *Euidella weedi* Van Duzee. In numbers they exceed all of the smaller leafhoppers, and in bulk were more than the approximate equivalent. The first three are more or less common neotropical inhabitants of lowland pastures and meadows, and are sometimes to be found on young sugar-cane. Their occurrence on white clover in the mountains of Haiti is only one more instance of how readily endemic insects become adjusted to flourishing, newly-introduced plant hosts, which have escaped from the pests attacking them in their country of origin.

1. Wolcott, G. N., The Minor Sugar-Cane Insects of Porto Rico. Jour. Dept. Agr. P. R., **5** (2) : 5–47, fig. 19. San Juan, April 1921.

2. Wolcott, G. N., An Animal Census of Two Pastures and a Meadow in Northern New York, Ecological Monographs, **7** (1) : 1–90, ref. 42. Brooklyn, January 1937.

3. Osborn, Herbert, Meadow and Pasture Insects, pp. 288, fig. 103. The Educator's Press, Columbus, 1939.

BENZENE HEXACHLORIDE AS A TERMITE REPELLENT

By GEORGE N. WOLCOTT [1]

As an experimental animal for indicating the duration or permanence of the residual effect of an insecticide or other chemical, the West Indian dry-wood termite, *Cryptotermes brevis* (Walker), is of value because its reactions are not affected by the age of the wood sample after this has become thoroly seasoned. In the evaluation of benzene hexachloride (hexachlorocyclohexane), the reactions of this termite show why this chemical may be of outstanding value in the protection of seasoning wood or bamboo against insects which normally attack it only at this time, but against the attack of which no chemical is needed a few months later when the material is completely seasoned.

Thru the courtesy of Dr. Harry F. Dietz of E. I. Dupont de Nemours & Co., a one gram sample of the pure gamma isomer of hexachlorocyclohexane was made available for test early in 1947, together with the technical 12% gamma, for comparison with a mixture of alpha and beta isomers purchased from Eastman. By comparison with a large number of other chemicals which have been tested in the laboratory, using standard technique (1), very few are as repellent to termite attack for so long a period (147 days) at a dilution of 0.05% as is the gamma isomer of benzene hexachloride. Yet, despite the continued residual resistence of the gamma isomer at greater concentrations, the sample impregnated with 2% gamma from solution in benzol, submerged ten minutes, was eventually eaten within less than a year. Because of the minute amount of the pure chemical available, no wood sample impregnated with a greater concentration than 2% of the gamma could be prepared for test. In actual commercial practice, however, if 2% of any chemical impregnated in a most susceptible wood fails to be repellent to termites over a long period of time, that chemical must be summarily dismissed as unsuitable for use as a termite repellent, valuable as it may be over shorter periods in protecting the wood against the attack of other kinds of insects. In-

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deed, as the pure gamma isomer is not commercially available now, and presumably will not become available in the near future, the use of the less repellent technical grades of benzene hexachloride for wood preservation against termite attack is not to be recommended.

The records of some other chemicals used, or suggested for use as termite repellents, are given in the accompanying table, for comparison with benzene hexachloride.

TABLE No. 1

DAYS AFTER SUBMERSION TEN MINUTES IN SOLUTION BEFORE ATTACK BY THE WEST INDIAN DRY WOOD TERMITE, *CRYPTOTERMES BREVIS* (Walker)

Dilutions of	0.05%	0.1%	0.2%	0.5%	1%	2%
Benzene Hexachloride:						
alpha & beta (Eastman)	1	5	7	10	15	44
12% gamma (DuPont)	23	37	44	91	260	264
100% gamma (DuPont)	117	189	249	259	303	334
D D T	25	27	29	35	37	uneaten over 4 years
Pentachlorphenol		10	13	273	337	uneaten over 4 years
Copper Pentachlorphenate	108	111	uneaten 40 months			
Tetrachlorxanthone	7	114	uneaten over a year			
Zinc Lake of Alizarin	5	uneaten over a year				

1. Wolcott, G. N., "Termite Repellents: a Summary of Laboratory Tests" Bulletin No. 73, Agr. Expt. Station, Univ. P. R., pp. 18, ref. 11. Río Piedras, October 1, 1947.

THE SYNONOMY OF *EMPOASCA FABALIS* DE LONG (CICADELLIDAE: HOMOPTERA)

JOHN S. CALDWELL
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Empoasca fabalis DeLong[1] was described from material collected April 15 and June 18, 1929 by Dr. R. C. Smith at Port-au-Prince, Haiti, and reported by him as "extremely abundant upon beans and sweet potatoes". Three years later *Empoasca batatae*[2] Poos was described from material reared on sweet potato in a green house at Arlington Farms, Virginia, and from material collected on the same host at Fort Myers, Florida. Subsequently the two names have remained in literature and have caused some confusion because only one species is involved. *Fabalis* DeL. has been reported as the most abundant form on beans in Puerto Rico. Recently Dr. Luis F. Martorell and myself spent over five months collecting *Empoasca* in Puerto Rico. The common form we found on beans proved to be *fabae* (Harris). The form taken on sweet potato and morning glory vines I identified as *batatae* Poos because the drawing of that form is more typical than the drawing for *fabalis* DeL. This raised the question and the suspicion that *batatae* was the same species as *fabalis*. After I took *batatae* (really *fabalis*) from morning glory at Port-au-Prince, Haiti, the type locality of *fabalis*, I was convinced that the two were the same species. As the request of Dr. G. N. Wolcott, Monsieur Léonce Bonnefil fils, Head of the Section of Entomology, Departement de l'Agriculture, Republique d'Haiti, forwarded two topotype collections from Damien, near Port-au-Prince, Haiti. The specimens from sweet potato were practically pure *fabalis* DeL. and the forms from bush beans were *fabae* (Harris). Later I have learned that Dr. Ralph H. Davidson considers *batatae* Poos to be a synonym of *fabalis* DeL. but has never published the fact, so I take this opportunity to do so now.

1. Can. Ent., 62:92, 1930.
2. Proc. Ent. Soc. Wash., 35:176–177, 1933.

A STUDY OF THE EFFECT OF SIX QUALITATIVE CHARACTER PAIRS ON YIELD AND COMPONENT CHARACTERS IN THE F_2 OF A CROSS BETWEEN TWO VARIETIES OF BARLEY [1]

By F. MARIOTA-TRÍAS [2]

INTRODUCTION

This article reports the relationship in barley between six qualitative character pairs and the quantitative characters: weight per seed, number of heads per plant, number of seeds per head, and yield per plant in the F_2 segregating population of a cross between the Nigrillaxum (*Hordeum distichon* L.) and Brachytic chlorina (*H. vulgare* L.) varieties of barley. The six pairs of genes studied differentiated 2-row *vs.* 6-row type of spike (V,v); black *vs.* white color of glumes (B,b); covered *vs.* naked caryopsis (N,n); hooded *vs.* awned type of lemma (K,k); normal *vs.* brachytic habit of growth (Br,br); and green *vs.* chlorina type of seedling (Fc,fc). The six contrasting characters of the parents were as follows:

$$\frac{\text{Nigrillaxum}}{\text{brachytic-chlorina}} = \frac{\text{V B n K Br Fc}}{\text{v b N k br fc}}$$

The data used for the study were taken by the late Dr. F. R. Immer, on material grown at University Farm, St. Paul. The quantitative data were taken on the individual F_2 plants and their genotypes were determined by F_3 progeny trials. The study consisted primarily of comparisons of the different genotypes for a single factor pair with respect to the quantitative characters. Similar comparisons were made of the interactions between factor pairs considered two at a time.

The mode of inheritance and linkage relations of the six factor pairs used are summarized by Robertson, Wiebe and Immer (13). Each of the characters is simply inherited and all are reported to be independent except br-fc which is linked

[1] Contribution from the Division of Agronomy and Plant Genetics, University of Minnesota, St. Paul, Minn. Scientific Journal Series, Minnesota Agricultural Experiment Station. Part of a thesis submitted to the faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of Master of Science. Dec. 1946.

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with about 9.8 per cent recombination. Two of the factor pairs namely 2-row vs. 6-row (11) and hooded vs. awned (10), have been reported to show a relation to yield. The recessive characters brachytic and chlorina are usually less vigorous than the normal.

Powers (11) reported the effect on quantitative characters of 3 of the 6 character pairs in a cross between *Hordeum deficiens* (Steud) and *H. vulgare* (L.). He found that the BB and bb genotypes did not differ significantly but that Bb was in general different from the two homozygotes. The vv plants yielded more than the VV and Vv; and the Vv more than the VV plants. Normal plants of the Br Br and Br br genotypes were higher in yield than the homozygous br br.

The reader may consult Smith (14) for a comprehensive review of the literature on quantitative inheritance and Hayes and Immer (6) for a review of quantitative inheritance in barley.

METHODS

The F_2 plants were grown in 1938, single seeds being planted five inches apart in rows one foot apart in a plot 18 ft. by 39 ft. in size. Three rows of each parent were planted as checks.

Notes were taken on the phenotype of each plant for the six character pairs, each plant was harvested individually and the number of heads per plant was recorded. The plants were threshed, the number of seeds counted and the yield in grams of seed determined, from which the average number of seeds per head and the average weight per seed were calculated.

Since the absence of hulls leads to a reduced weight per seed, corrections were made on the yield data for the hulles plants based on a regression between seed weight and hull weight determined from 25 seeds of each of 48 plants representing a wide range of phenotypic combinations.

The complete genotypes of the F_2 plants were determined by classifying the F_3 progeny. Of the F_2 plants, 6 of the Br Fc, 12 of the br Fc, 4 of the Br fc, and 94 of the br fc produced insufficient seed for the F_3 test (less than 0.5 grams) and were discarded leaving a total of 1044 plants.

The complete quantitative data and their squares, and the genotypes for each of the 1044 plants were punched on cards. Ordinarily the cards would then have been sorted by genotypes

to obtain the data for each gene pair singly and also in combinations of two or more gene pairs at a time. In this case, since a large proportion of the F_2 plants with insufficient seed were *br, fc* or *br fc*, making the yield of these genotypes higher than they should be, it was deemed necessary to remove the effects of the Br, br and Fc, fc segregation by including their different observed genotypes with each of the genotypes for the gene pair or pairs being studied. Consequently the cards were sorted for all genotypic combinations between the gene pair or pairs being studied and Br, br, Fc, fc.

In order to study the effects of the qualitative genes on each quantitative character, the mean value for each genotype was calculated and used in the comparisons. For example, the difference Vv-vv was interpreted as the effect of substituting the first dose of the dominant gene; VV-Vv the effect of substituting the second; and VV-vv the total effect of both. In studying the interactions between two non-allelic genes, for example, V,v with B,b; the above three comparisons were made in each of the BB, Bb, and bb genotypes. Finally, the effect in one of these latter genotypes was compared with that in each of the other two. For example the Vv-vv effect in the BB genotype was compared with that in the Bb and bb genotypes.

The statistical methods for calculating the means and standard errors and for determining the significance of differences will now be described.

Statistical Methods

The method of removing the effects of the Br, br and Fc, fc segregation will be illustrated by the calculation for the yield of a genotype used in the study of the interaction between V,v and B,b. To obtain the corrected sum of squares of the yields for the VVBB genotype, that is, freed from the effects of segregation for Br, br and Fc, fc, an analysis of variance for individual plant yield for each of the different genotypic combinations between (Br *vs.* br) (Fc *vs.* fc) within the VVBB genotype was calculated separately and the totals combined. The formula used is as follows:

"the sum of squares" $= S(y)^2 - S(y)\bar{y}$, where: $S(y)$ = sum of the yields of all plants, $\bar{y}$ = mean yield of the plants of the given genotype and y = yield of individual plants.

The results of the calculations for the VVBB genotype are given in Table 1. Since there are 69 plants in the VVBB segregation composed of 7 classes for Br, br *vs.* Fc, fc, the degrees of freedom will be 69-7 = 62. The total sum of squares, 350.75, divided by the degrees of freedom, 62, is the variance or mean square. The variance of the mean was determined from the formula: $Vm = \frac{\text{Total sum of squares.}}{\text{D.F x N}}$ This method of calculating the variance combines the differences between the genotypic combinations between Br, br and Fc, fc into a single value, this being used to calculate a generalized estimate of the error for that particular genotype of V with B.

TABLE No. I

LLUSTRATION OF THE METHOD OF CALCULATING THE CORRECTED SUM OF SQUARES OF THE YIELDS OBTAINED WITH A GIVEN GENOTYPE (VVBB) FOR ALL COMBINATIONS OF THE QUALITATIVE CHARACTERS Br br AND Fc fc[1]

Genotype	N	S(y²)	S(y)($\bar{y}$)	S(y²)—S(y)($\bar{y}$)
VVBBBrBrFcFc	17	745.83	613.20	132.63
VVBBBrBrFcfc	5	243.24	233.93	9.31
VVBBBrBrfcfc				
VVBBBrbrFcFc	5	246.36	228.49	17.87
VVBBBrbrFcfc	31	1,265.67	1,079.11	186.56
VVBBBrbrfcfc	2	3.94	3.92	.02
VVBBbrbrFcFc				
VVBBbrbrFcfc	4	18.78	15.21	3.57
VVBBbrbrfcfc	5	5.99	5.20	.79
	69			350.75*

* Corrected sum of squares for VVBB.

1 The method of removing the effects of Br br vs. Fc fc was suggested by W. G. Cochran in a letter to Dr. F. R. Immer.

TABLE No. II

ILLUSTRATION OF THE METHOD OF CALCULATING THE MEAN SQUARES, AND VARIANCE OF THE MEAN USING "SUM OF SQUARES" CORRECTED BY REMOVING THE Br br VS. Fc fc EFFECTS

Genotype	N	Classes	D. F.	Mean Yield	Corrected Sum of Squares	Mean Square	Variance of mean
VVBB	69	7	62	5.343	350.75	5.6572	.081989
VVBb	122	7	115	5.163	959.01	8.3392	.068354
VVbb	79	7	72	5.589	791.72	10.9961	.139191
VvBB	144	9	135	6.356	1,217.66	9.0197	.062637
VvBb	267	7	260	5.745	2,961.78	11.3915	.042665
Vvbb	114	8	106	5.818	960.81	9.0642	.079511
vvBB	62	7	55	6.082	614.19	11.1671	.180114
vvBb	116	7	109	6.217	1,278.07	11.7254	.101081
vvbb	71	8	63	5.159	740.58	11.7552	.165567
	1,044	67	977		9,874.57		

Table 2 summarizes the calculations for the nine genotypes for the factor pairs V,v and B,b. To determine if a single generalized error could be used for the 9 genotypes insolving V,v and B,b, a homogeneity test (1) was applied to the 9 separate generalized errors. The writer found heterogeneity as Powers (11) did in his study. Since the variance were not homogeneous, and a generalized estimate of error could not be used, "t" values to determine the significance of mean differences between genotypes were calculated by the usual formula for $s_{\bar{d}}$, the standard error of a difference between two means:

$s_{\bar{d}} = \sqrt{V_1 + V_2}$, where V_1 and V_2 are the respective variances of the means under comparison.

As an example, the effect of VV will be compared with that of Vv in the BB genotype, taken from Table 2. For VVBB, $V_1 = 0.081989$ and VvBB, $V_2 = 0.062637$.

Then $s_{\bar{d}} = \sqrt{0.081989 + 0.062637} = .3803$

Since the ratio of the difference between means, $\bar{d}$, to its standard error, $s_{\bar{d}}$, does not follow Student's "t" distribution except in special instances (2), some other method must be used. The approximation t′ given by Cochran and Cox (2) was used. The approximation consists in calculating $t = \frac{\bar{d}}{s_{\bar{d}}}$ and finding a significance level t′ weighted in accordance with the following procedure:

$t' = \frac{w_1 t_1 + w_2 t_2}{w_1 + w_2}$ * where t_1 and t_2 are the significance level values for n_1 and n_2 degrees of freedom and $w_1 = V_1$ and $w_2 = V_2$, the latter being the variances of the two means. In the present example for VVBB-VvBB at the 5% level:

$$t' = \frac{(.081989 \times 1.995) + (.062637 \times 1.977)}{.081989 + .062637} = 1.987.$$

* Since $w_1 = V_1$ and $w_2 = V_2$, this formula becomes $t' = \frac{V_1 t_1 + V_2 t_2}{V_1 + V_2}$

Since t' always lies between the ordinary t values for n_1 and n_2 degrees of freedom, all cases except those on the borderline of significance can be decided without the actual calculation of t'. Since the difference in mean yields is:

VvBB — VVBB = 6.356 — 5.343 = 1.013,

$$\text{then } t = \frac{\bar{d}}{s_{\bar{d}}} = \frac{1.013}{.3803} = 2.664$$

In this example the observed "t" value of 2.664 is well above not only this t' value, but also the "t" value of 1.995 corresponding to the 5% level for 62 degrees of freedom. Therefore it would not have been necessary to calculate t' for this comparison.

For the effects of the different genotypes for each gene pair considered singly, the mean value of the corresponding quantitative character for each was calculated and the corresponding variance of the mean determined by using the corrected "sum of squares" as described above to remove the effects of the Br, br and Fc, fc segregation.

The net effects of V *vs.* v in the population classified for each of the other gene pairs considered singly were also calculated from data in which the interactions were studied. For example, for the V-v pair in the population classified for B *vs.* b the following values were calculated from the data in table 2.

Genotype	N	D. F.	Totals of yields	Corrected sum of squares	Variance of the mean
VV	270	219	16.095	2,101.48	.031278
Vv	525	501	17.919	5,149.26	.019543
vv	239	227	17.458	2,632.84	.046580

For the net effect of adding one V, we have
Vv-VV = 17.919 — 17.458 = .461 (net effect),

$$\text{and } t = \frac{.461}{\sqrt{.019543 + .046580}} = 1.794, \text{ significance being}$$

determined as before. In general these net effects should agree with the effects of each gene based on the total population. Any differences result from the fact that the net effects are based on means for genotypic combinations between two pairs of factors, the grouping being different for different cases. In determining the effects of the Br-br and Fc-fc gene pairs con-

sidered singly, mean values and their variances were calculated for each quantitative character directly in spite of the possible bias due to the elimination of a large number of the recessives. Had they been included, the differences would have been still larger.

Interactions (To determine whether a gene effect in one of the three genotypic backgrounds for a second gene pair was significantly different from its effect in either of the other two genotypic backgrounds for this gene pair).

Since an analysis of variance could not be calculated to test the significance of the interactions of one gene with a non-allele, the "t" values to determine the significance of the first order interactions were obtained by the method given by Powers (12). The formula for obtaining t as stated by him is as follows:

$$t = \frac{\bar{x}_1 + \bar{x}_4 - \bar{x}_2 - \bar{x}_3}{\sqrt{\frac{S_1^2}{n_1 n_1'} + \frac{S_2^2}{n_2 n_2'} + \frac{S_3^2}{n_3 n_3'} + \frac{S_4^2}{n_4 n_4'}}} \quad \text{or} \quad \frac{\bar{x}_1 + \bar{x}_4 - \bar{x}_2 - \bar{x}_3}{\sqrt{V_1 + V_2 + V_3 + V_4}}$$

In the above formula $\bar{x}_1$, $\bar{x}_2$, $\bar{x}_3$ and $\bar{x}_4$ are the mean of the different genotypes: S_1^2, S_2^2, S_3^2 and S_4^2 are the sum of squares for the estimation of the separate errors; n_1, n_2, n_3 and n_4 are the corresponding degrees of freedom available for an estimation of the separate errors; and n'_1, n'_2, n'_3, and n'_4 are the corresponding total numbers of individuals for the genotypes whose means are involved in the calculation of the interaction.

As an illustration of this calculation of interaction, the following data for yield from Table 2 may be used: (Vv BB — vvBB) — (Vv Bb — vv Bb) = (6.356—6.082) — (5.745—6.217). In other words the Vv-vv effect is being compared in the BB and Bb backgrounds.

$$t = \frac{6.356 + 6.217 - 6.082 - 5.745}{\sqrt{\frac{1217.66}{(135 \times 144)} + \frac{614.19}{(55 \times 62)} + \frac{2961.78}{(260 \times 267)} + \frac{1278.07}{(109 \times 116)}}}$$

$$= \frac{6.356 + 6.217 - 6.082 - 5.745}{\sqrt{0.062637 + 0.180114 + 0.042665 + 0.101081}} = \frac{.746}{.6217} = 1.200$$

For these "t" tests of significance, all values found to exceed 1.960 were considered significant at the 5% point, since the total number of degrees of freedom in each test was always very large.

The mean, variance, variance of the mean and the standard errors of the yields and its components were calculated for the six character pairs singly and in all combinations of two each. Differences giving probabilities as low or lower than 0.05 that the deviations as great as those noted might arise because of errors of random sampling were considered to be statistically significant; although some caution must be exercised since with such a large number of comparisons, certain of them are undoubtedly chance variations.

EXPERIMENTAL RESULTS

Each factor pair except Fc-fc in F_2 and all of them in F_3 gave good agreement with a monogenic ratio as expected from previous studies (13). For the Fc *vs.* fc pair there was a deficiency of chlorina plants in F_2 due possibly to low germination or poor survival.

The X^2 values for the linkage components indicated no association except between Br,br and Fc,fc factor pairs and between N,n and K,k. All other combinations of two factor pairs showed a good fit to dihybrid segregations. The F_2 data on which these are based are in table 3.

TABLE No. III

F_2 SEGREGATIONS FOR CHARACTERS SHOWING LINKAGE, F_2 DATA

Segregation	AB	Ab	aB	ab	Total	Linkage Component		Per Cent Recombination Product Method	Weighted p value F_2 and F_3 Data
						X^2	P		
N-K	575	200	210	59	1,044	1.63	.30 - .20	47.0±2.40	46.1±1.71
Br-Fc	860	21	32	131	1,044	376.10	.0001	6.3± .78	7.6± .58

The loose but significant linkage btween N and K suggests a chromosome abnormality, possibly a translocation, but was not found in time for a cytological study. The interpretations of the results may be affected since two closely linked qualitative factors might be expected to show similar associations with linked quantitative factors.

Main Effects—Differences Between Genotypes for Each Gene Pair Considered Singly

The average values for yield and its components for the homozygous and the heterozygous genotypes are in table 4 and the comparisons for each gene pair are in table 5. Any observed difference may be interpreted either as due to the effect of the gene itself or to the effect of one or more linked quantitative factors. If the latter, the observed degree of effect will depend on the closeness of the linkage, i.e. the closer the linkage the more nearly will the observed difference represent the actual effect of the quantitative gene itself. For ease of discussion the difference will be described as due to the effect of the qualitative factor itself throughout the presentation of the results, although in reality it may be due to an association with a quantitative factor.

The comparisons between genotypes for a given gene pair, for example Vv-vv, VV-Vv, and VV-vv, are interpreted as being the effect of substituting the first dominant, the second dominant, and both respectively for either or both recessive alleles. The effect of the second dominant is the effect of adding another one to a genotype which already has one. The VV-vv difference is the algebraic sum of the other two.

Table No. IV

A Summary of Quantitative Character Means for the Different Genotypes Considered Singly

Genotype	N	Mean yield in grams of seeds per plant	Mean number of heads per plant	Mean number of seeds per head	Mean weight of seed in grams per seed
VV	270	5.331	9.211	154.65	.032384
Vv	525	5.929	9.265	223.46	.025778
vv	249	5.882	7.921	261.59	.021481
BB	275	6.040	9.516	225.12	.026812
Bb	505	5.713	8.824	213.51	.026514
bb	264	5.572	8.527	206.34	.025997
NN	276	5.832	8.887	222.70	.026170
Nn	499	5.674	8.894	211.25	.026344
nn	269	5.859	9.045	213.15	.026970
KK	264	5.153	9.015	197.11	.025725
Kk	521	5.720	9.142	214.13	.026678
kk	259	6.455	8.420	234.00	.026776
BrBr	360	6.639	10.006	253.81	.026681
Brbr	521	6.602	9.994	236.73	.028603
brbr	163	1.148	3.160	58.26	.019154
FcFc	333	6.585	10.048	248.92	.026952
Fcfc	559	6.601	9.968	240.46	.028110
fcfc	152	.885	2.671	45.39	.019354

TABLE No. V

DIFFERENCES IN QUANTITATIVE CHARACTER MEANS BETWEEN GENOTYPES FOR INDIVIDUAL CHARACTER PAIRS CONSIDERED SINGLY

Genotype	Difference between mean yields	Difference between mean number of heads	Difference between mean number of seeds	Difference between mean weight of seed
Vv-vv	.047	1.311**	38.13**	.004297**
VV-Vv	.595*	.054	68.81**	.006605**
VV-vv	-.548*	1.287**	-106.95**	.010903**
Bb-bb	.141	.297	7.17	.000517
BB-Bb	.327	.692*	11.61	.000298
BB-bb	.468	.989**	18.78	.000815
Nn-nn	.185	-.151	1.90	.000635
NN-Nn	.158	-.007	11.45	.000174
NN-nn	-.027	-.158	9.55	.000809
Kk-kk	-.726**	.722*	19.87*	.000098
KK-Kk	-.576**	.127	-17.02*	-.000953*
KK-kk	1.302**	.595	-36.89**	.001051*
Brbr-brbr	5.451**	6.831**	178.47**	.009450**
BrBr-Brbr	.037	.012	17.08	.001920**
BrBr-brbr	5.491**	6.846**	195.55**	.007530**
Fefe-fefe	5.716**	7.297**	195.07**	.008760**
FeFe-Fefe	.016	.080	8.46	-.001160*
FeFe-fefe	5.700**	7.377**	203.53**	.007600**

* Significant at the 5% probability level.
** Significant at the 1% probability level.

Effect of 2-row versus 6 row (*V vs. v*). There was no effect on yield due to the substitution of the first dominant as measured by the Vv-vv comparison. The substitution of the second V as measured by the VV-Vv comparison significantly decreased yield. The total effect of substituting both V's as measured by the VV-vv comparison was a significant decrease in yield.

The substitution of the first V significantly increased the number of heads per plants, the second V had no effect, while the total effect of both was to significantly increase the number of heads.

For number of seeds per head the first V produced a decrease, the second V reduced it still further, and the total effect of both was necessarily a significant decrease.

As to average weight per seed the first V increased it significantly, the second V increased it still further and again the effect of both was, as expected, a significant increase.

The effect of the first V to increase number of heads and weight per seed was counterbalanced by a decrease in number of seeds, the net result being no effect on yield. The substitution of the second V had no further effect on number of heads,

but decreased the number of seeds and increased the weight per seed. The decrease in number of seeds per head accounts for the net decrease in yield as a result of substitution of the second V. These comparisons thus represent the change from 6- to 2-row.

Effect of black versus white color of glumes (*B vs. b*). There was no effect on yield, number of seeds per head nor weight per seed due to the substitution of the first or the second B or of both.

For number of heads per plant the substitution of the first B had no effect. However, the second B significantly increased the number of heads per plant, and the total effect of both B's was a significant increase. In spite of this, there was no significant net effect on yield.

Effect of covered versus naked caryopsis (*N vs. n*). No one of the quantitative characters was affected by substituting either the first or second N or both.

Effect of hooded versus awned lemma (*K vs. k*). The substitution of the first K significantly decreased the yield, the second K decreased it still further, while the effect of both K's was necessarily a significant decrease.

There was an increase in number of heads per plant due to the substitution of the first K.

As to number of seeds per head the first K decreased it significantly, the second K decreased it still further, while the total effect of both K's was a significant decrease.

For weight per seed the first K had no effect, while the substitution of the second K and of both K's significantly decreased it.

The significant decrease in yield due to the substitution of the first K appears to have been brought about mainly by a decrease in seed number, since the number of heads was actually increased. The decrease in yield attributed to the second K seems to have been the result of a decrease in weight of seeds as well as in number of seeds.

Effect of normal versus brachytic habit of growth (*Br vs. br*). The substitution of the first Br produced a significant in-

crease in the yield, number of heads, number of seeds and weight per seed. The second Br had no effect, except to decrease the weight per seed. The total effect of both was a significant increase in yield, number of heads, number of seeds and weight per seed. As to weight per seed the heterozygous Br br seeds were heavier than either of the homozygotes, an indication of heterosis or of Hull's superdominance (7).

Effect of normal versus chlorina seedlings (Fc vs. fc). The substitution of the first Fc produced a significant increase in the yield, number of heads per plant, number of seeds, and weight per seed. The second Fc had no effect except to decrease weight per seed. The total effect of both F'cs was a significant increase in yield, number of heads, number of seeds, and weight per seed. The heterozygous (Fcfc) seeds were heavier than the homozygous ones, again an indication of heterosis.

Interactions of each gene pair with a non-allelic pair. Two questions will be considered here: first, in which genetic backgrounds is a given gene effect significant; and second, are there effects which are significantly different in the different genotypes for a given non-allelic gene pair. For brevity, only the data on the interactions of the V-v pair with non-alleles are presented, information on the first question being in table 6. Information on the second question is in table 7. It is helpful in interpreting the latter tables to refer to the corresponding tables 6 and 7 to determine the magnitude and direction of the differences being compared. For example, the significant interaction (VVBb-vvBb)—(VVbb-vvbb) = —1.484 (table 7) is a comparison between (VVBb-vvBb) = —1.054 and the (VVbb-vvbb) = .430 given in table 6. Interactions of the other gene pairs will be discussed without presenting the data.

TABLE No. VI

QUANTITATIVE CHARACTER DIFFERENCES BETWEEN GENOTYPES FOR THE V vs. v CHARACTER PAIR WITHIN DIFFERENT GENOTYPES FOR A NON-ALLELIC PAIR

	Yield				Number of heads		
	B vs. b	N vs. n	K vs. k		B vs. b	N vs. n	K vs. k
				Vv vv			
AA	.274	.073	.098		2.032*	.967	1.500**
Aa	.472	.136	.361		.541	1.550**	1.355**
aa	.659	.014	.291		1.919*	1.395**	1.085
				VV Vv			
AA	1.013*	1.570**	.220		.488	.482	-.122
Aa	.582	.555	.430		.137	.205	.119
aa	.229	.149	1.308*		.553	.550	.252
				VV vv			
AA	.739	1.643**	.318		1.541*	.185	1.378*
Aa	1.054*	.119	.063		.404	1.345**	1.236**
aa	.430	.193	1.599*		2.172*	1.945**	1.337

	Number of seeds				Weight per seed		
	B vs. b	N vs. n	K vs. k		B vs. b	N vs. n	K vs. k
				Vv vv			
AA	22.65	49.90*	41.69*		.003331**	.005938**	.001788**
Aa	65.91**	31.06*	32.74**		.004573*	.003413**	.004395**
aa	6.44	37.09	40.83		.001361**	.003924**	.003570**
				VV Vv			
AA	83.78**	88.50**	56.62**		.007229**	.003814**	.005941**
Aa	64.73**	71.80**	61.98**		.006251**	.007516**	.007060**
aa	62.68**	46.59**	98.50**		.006845**	.007458**	.006635**
				VV vv			
AA	106.43**	128.10**	95.31**		.010560**	.009752**	.010724**
Aa	130.64**	102.36**	94.72**		.010827**	.010959**	.011455**
aa	69.12**	83.68**	139.33**		.011209**	.011382**	.010205**

TABLE No. VII

SIGNIFICANT INTERACTIONS OBTAINED BETWEEN A GIVEN EFFECT OF V vs. v AND DIFFERENT GENOTYPES FOR A NON-ALLELIC PAIR

Interactions	Difference
YIELD PER PLANT:	
(VVNN-VvNN)-(VVnn-Vvnn)	1.719**
(VVNN-VvNN)-(VVNn-VvNn)	1.015*
(VVNN-vvNN)-(VVnn-vvnn)	1.836*
(VVBb-vvBb)-(VVbb-vvbb)	1.481*
AVERAGE NUMBER OF HEADS PER PLANT	
(VvBB-vvBB)-(VvBb-vvBb)	1.491*
(VvBb-vvBb)-(Vvbb-vvbb)	1.378*
(VVBb-vvBb)-(VVbb-vvbb)	2.068*
AVERAGE NUMBER OF SEEDS PER HEAD:	
(VvBb-vvBb)-(Vvbb-vvbb)	59.17*
(VVNN-VvNN)-(VVnn-Vvnn)	41.91*
(VVKK-VvKK)-(VVkk-Vvkk)	44.88*
(VVBb-vvBb)-(VVbb-vvbb)	61.52**
AVERAGE WEIGHT PER SEED:	
(VvNN-vvNN)-(VvNn-vvNn)	.002495**
(VVNN-VvNN)-(VVNn-VvNn)	.003702**
(VVNN-VvNN)-(VVnn-Vvnn)	-.003644**

Interactions of V-v. For average yield per plant, table 6 shows that the substitution of the first V had no significant effect in any of the genotypes of B-b, N-n, and K-k. The second V significantly decreased the yield only in the BB, NN and kk genotypes. The effect of both V's was significant only in the Bb, NN, and kk genotypes. Table 7 shows that the effect on yield of the second V, as measured by VV-Vv, was significantly different in the NN as compared with either the Nn or nn genotypes. The effect of both V's was significantly different in the NN *vs.* nn; and also in the Bb *vs.* bb genotypes. All other effects on yield were not significantly different in the three genotypes for any given non-allelic pair.

For average number of heads per plant, (table 6), the substitution of the second V was in no case significant in any of the non-allelic backgrounds. Substitution of the first V resulted in a significant increase in all cases except in the Bb, NN and kk genotypes. The effect of both V's was also significant in all cases except in these same genotypes. The effect of the V *vs.* v for number of heads is only significantly greater, (table 7), in the BB and bb genotypes than in Bb. The effect of both V's in bb was greater than in Bb.

In the study of average number of seeds per head, the first V produced a significant decrease, (table 6), in the Bb, NN, Nn, KK and Kk genotypes. The second V produced much greater reductions which were highly significant in all genotypes. The addition of both V's was also significant in all genotypes. The decrease due to the first V was greater, (table 7), in the Bb than in the bb genotype. The further decrease due to the second V was greater, in the NN than in the nn genotype and in the kk than in the KK genotype. The decrease due to both V's was greater in the Bb than in the bb genotype.

For average weight per seed, the first V brought about a highly significant incresae in all cases (table 6). The second V still further increased the seed weight by a highly significant amount in all cases. The increase due to the first V was greater, (table 7), in the NN than in the Nn genotypes. The increase due to the second V were greater in the NN than either the Nn or the nn genotypes.

The chief component to account for the decreased yield in certain genotypes was the decrease in average number of seeds per head, since seed weight was increased in all genotypes.

Interactions of K vs. k. For average yield per plant, the effect of the first K was to significantly decrease yield in the Vv, vv, Bb, Nn and nn genotypes (all P* except in nn, P**). Addition of the second K decreased the yield only in the Vv, Bb and nn genotypes. The total effect of both K's was to decrease the yield in the Vv, vv, Bb, Nn and nn genotypes (P** for all but vv and Nn for which P*). The effect in yield of the first K was significantly different in the NN *vs.* nn genotypes (P**). The effect of the second K was different in the Bb and BB genotypes (P*) and in the Nn and nn genotypes (P**). The total effect of both K's was significantly different in BB and Bb (P*), NN *vs.* Nn and nn genotypes (P**).

For number of heads per plant, the effect of the first K, the second K and of both was not significant in any genotype. The total effect of both K's was different in the Nn and nn genotypes (P*).

For number of seeds per head, the effect of the first K was negative and significant (P*) in the Vv, and nn genotypes. The effect of the second K was significant in the Bb and nn genotypes. The effect of both was significant (P**) in the Vv, Bb and nn genotypes. The total effect of both K's was different in VV and Vv and in NN and nn (P*) genotypes.

For weight per seed the first K had no significant effect. The second K decreased the weight (P*) in the VV and vv genotypes. The total effect of both was a decrease in weight in the vv, Bb and nn genotypes. The effect of the first K was different in the NN and nn genotypes (P*). The effect of both K's was different in NN and nn genotypes (P*).

Interactions of B vs. b. For average yield per plant there was a significant increase in yield of BB over bb (P*) in the NN genotype, and in the vv genotype for the Bb-bb (P*) comparisons. In the BB-Bb comparisons there were significant differences in the KK (P**) genotype. There appeared to be a trend in favor of higher yield of the BB genotype, although this may be due to chance, since the net difference was not significant. The effect on yield of the first B was greater (P*) in the vv than in the VV genotype. The second B effect was greater (P*) in the KK than in either the Kk or kk genotypes.

For average number of heads per plant, significant differences in favor of BB over Bb plants were found in the Vv, Nn

P* means that the difference so qualified was significant at the 5% point.
P** means that the difference so qualified was significant at the 1% point.

and KK genotypes. In the BB-bb comparisons, there were significant differences in favor of the BB genotype in Vv, NN and Nn. The effect of the first B was greater (P*) in the vv than in either the Vv or the VV genotypes. The effect of the second B was greater in the Vv than in the vv genotype (P*).

For number of seeds per head, the effect of the first B was a significant increase (P*) in the vv genotype. The effect of adding the second B was an increase only in the Vv, and KK genotypes, (P*). The total effect of both was significant only in the NN genotype (P*). The effect of the first B was greater in the vv than in either the VV or the Vv genotype.

For average weight per seed, the increase due to the first B was significant only in the NN genotype (P*). The effect of the second B was significant in no case. Only in the vv genotype was the total effect of both B's significant (P*) while the individual effects in this vv genotype were not. The effect of the first B was greater (P*) in the NN than in the nn genotype.

N vs. n interactions. For average yield per plant, the addition of the first N produced no significant effects. The same was true for the addition of the second N. The total effect of both was significant and negative in the VV (P**) genotype, positive in the KK (P*) and negative again in the kk genotype. In other words, the total effect of both was to depress the yield in the presence of kk; and to increase it in the presence of KK. The effect on yield of the first N was to increase the yield in the KK genotype and decrease it in the Kk and kk genotypes. The effect of the second N was to increase the yield VV and to decrease it in the Vv. The effect of both N's was different in the VV than in the Vv and vv (P*) and in the kk from that in either the KK (P**) or the Kk (P*) genotype.

For number of heads per plant, in no case was there any specific interaction with a non-allelic genotype. The effect of the first N was different in the kk genotype where there was a decrease in number of heads while in the KK there was an increase in number of heads.

For number of seeds per head, in the VV genotype the total effect of both N's was to significantly decrease the number of seeds per head (P*). The effect of the first N was different in the KK from that in the kk genotype (P*). The effect of

both N's was significantly different in the VV from that in the Vv genotype (P*) and in the KK from that in the kk genotype (P*).

For average weight per seed, addition of the first N significantly (P*) decreased weight per seed in the bb genotype. Addition of the second N affected seed weight in the VV (P*) and Vv (P**) genotypes. In the former the weight was decreased, in the latter it was increased. The total effect of both N's was significant and negative in the VV (P**), bb (P*), and kk (P**) genotypes. The effect of the second N was different in the Vv from that in either the VV or vv genotypes (P**). The effect of both N's was different in the VV from that in the Vv genotype (P**); in the bb from the Bb genotype (P*) and in the kk from that in either the KK or Kk genotypes (P*).

Discussion of Results

Before attempting to interpret the differences found to be statistically significant, it is necessary to point out that in such a large number of comparisons as was made in this study, a few of them are actually only chance differences. Which ones they are, cannot be recognized. To be safe, those which do not appear to be consistent are regarded with suspicion. In a study of sampling using Student's distribution, Treloar and Wilder (15) studied this problem to which the reader is referred if interested.

Certain of the qualitative characters were consistently associated with differences in the quantitative ones, and will be discussed here. Many of the associations can be interpreted as results expected from the known morphological or physiological differences brought about by the qualitative characters.

The higher yield of awned lemma (kk) over hooded (KK) is probably due to the favorable physiological effect of the presence of the awn which has been reported by many workers (review in Hayes and Garber (5)). The higher yield of the 6-rowed (vv) over the 2-rowed (VV) plants may be accounted for by a greater number of seeds per head since the laterals of the 2-row plants (VV) are infertile.

A higher number of seeds per head, one of the major components of yield, was found associated not only with the vulgare type of spike (vv) but also with awned lemma (kk). The

latter does not naturally follow except possibly from a physiological effect of the awn. The higher weight per seed associated with 2-row type of spike (VV) and awned lemma (kk) may have similar explanations. The seed of the 2-row types is expected to weight more since the central row seeds usually are larger than those in the laterals (8). Also the reduced seed number per head, in 2-row as compared with 6-row may result in increased seed size. The higher weight per seed of awned lemma (kk) over hooded (KK) may de due to the favorable physiological effect of the awn.

Higher number of heads per plant was associated with 2-row type of spike (VV) and with black color of glumes (BB). The latter may be due to an association of the BB character pair with quantitative factors which in their total effect produced more heads per plant.

The results obtained in this study of the cross between *Hordeum distichon* and *H. vulgare* are similar to those obtained by Powers (11) for the V,v and Br, br factors pairs. Powers found that Bb plants yielded more than either of the two homozygotes. In the present study there was no such evidence of heterosis in the B *vs.* b pair. Perhaps this latter result would lead to the conclusion that the B *vs.* b factors themselves were not the cause of the greater vigor observed by Powers.

In the present study manifestations of heterosis were found for weight per seed in the heterozygotes, Br br and Fc fc, when compared with their respective homozygous types. Similarly these results may not have been caused by the factors themselves since Powers did not obtain this. Since there is no manifestation of heterosis for yield or the other components, this one effect does not appear very conclusive. The brachytic (br br) and chlorina (fc fc) character mutations may be classified as physiological defectives according to East's (3) terminology. The brachytic and chlorina genes produce weak plants, but are not lethal. Gustafsson (4) presents a hypothesis according to which mutations in plants, many of which are lethal in homozygous condition, increase vigor when they occur in a single dose. Isogenic stocks would furnish better material for the study of the effects of the qualitative genes themselves, although even then closely-linked quantitative factors may still be present to affect the results.

In the study of quantitative inheritance there are possibilities of errors due to metrical bias. This bias is due to the inherent relation between the scale of measurements and the phenotypic expression. This may or may not have genetical significance and can be removed by an appropriate transformation of scales (9), but by so doing information on certain of the interactions is sacrificed.

Since in the present study the aim was to study the effects of the different genes and their interactions no transformation of scales to account for metrical bias was made.

Summary

1. Certain statistical methods that have been used for studies of quantitative inheritance are presented together with illustrations of their application.

2. The effect of the substitution of the first dominant, second dominant and the effect of both were calculated as the following differences between genotypes: Aa-aa, AA-Aa and AA-aa respectively, the latter being the algebraic sum of the other two.

3. Significant associations between certain qualitative and quantitative characters were found. Of the significant effects, there were several in which the first dominant produced the full effect, several in which the second produced the full effect, while in a few each produced an effect.

4. The vv (6-row) genotype was higher in yield than VV (2-row) while kk (awned) was higher in yield than either Kk or KK (hooded). Higher number of seeds per head and lower weight per seed were found in vv than in either Vv or VV. The kk genotype had a higher weight per seed than KK and a higher number of seeds per head than either Kk or KK.

5. For the most part, the above associations are explainable as expected from the known morphological or physiological effects caused by the factor pairs.

6. The *Br* and *Fc* factors were associated with higher yields and were higher in all components than the homozygous recessives.

7. The N *vs.* n gene pair showed no differential effects, indicating that a high-yielding naked barley is a definite possibility.

8. When the effects of a given gene pair are considered in the different non-allelic genotypes it was found that the V *vs.* v and K *vs.* k as a general rule were very consistent in their effects in all genotypes.

9. For the other gene pairs, certain genotypes showed specific interactions with certain non-allelic genotypes. For example, the addition of the second N decreased the weight per seed in the VV while it increased it in the Vv genotype. Also the effect of N on yield was an increase in KK plants and a decrease in kk plants.

10. The nature of these interactions was such as to permit no general conclusions. While several of them may have been due to chance, it seems clear from the number obtained that such specific interactions are a part of the general picture as to the action of quantitative factors.

11. An unexpected linkage was found between K and N of 46.1 $\pm$ 1.71. A cytological study was not made to determine the cause of this unexpected result although a translocation is suspected.

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STUDIES ON VIRUS DISEASES OF PAPAYA (CARICA PAPAYA) IN PUERTO RICO [1]

I. Transmission of Papaya Mosaic

By JOSÉ ADSUAR [2]

INTRODUCTION

A survey of the available literature (1-14) demonstrates the presence of a serious mosaic disease of papayas (*Carica papaya*) widely spread throughout different regions of the world. In spite of this fact, surprisingly little is known as to the nature of the virus or viruses involved, means of transmission, dissemination, etc. As far as we have been able to determine, only four papers (1, 2, 6, 8) deal at any length with the problem and in only one of them (8) is there a serious claim as to the successful transmission of the disease.

In Puerto Rico, a disease of papaya known under the name of *bunchy top* was first reported in 1931 by Cook (3, 4) but it was not until 1937 that its epidemic proportions were noticed at the Isabela Substation, during the course of extensive trials conducted with the purpose of studying the possibilities of large scale commercial plantings. So severe was the attack by the following year, that the Station authorities declared the disease to be the limiting factor in the successful commercial development of this promising crop in the Island.

Almost simultaneously with the outbreak at Isabela, Jensen (6), working at the Federal Experiment Station at Mayagüez, undertook a study of the disease. He was not able to transmit it either mechanically or by grafting, but obtained evidence through field experiment that it was probably insect transmitted. As to the insects concerned, he did some preliminary experiments but without definite results.

For the past two years we have been engaged in the reinvestigation of papaya mosaic in Puerto Rico. As a result, three severe diseases, presumed to be caused by viral infection, have been identified among the papayas of the Island. The commonest of these is typical *bunchy top* disease, involving stunting;

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failure of latex flow on wounding; slow growth of short, stiff, nearly horizontal petioles; supporting small, thick, chlorotic leaves. A less common type of disease sometimes called *die-back* is distinguished by a severe chlorosis and defoliation from just below the growing point, progressing downward, and usually followed by necrosis of the tip of the stem or of the whole plant. In a small area of the Island including Guánica and Ponce, a typical *mosaic* disease seemed to replace the other types. This

FIG. 1—Left to right, leaves from diseased plants, showing deformation of leaf lamina. Extreme right, healthy leaf.

mosaic is characterized by mottling and extreme distortion of leaves, and also by the presence of green and brown rings on the fruits. It is still a question whether this mottling disease is closely related to typical *bunchy-top* and *die-back*, but the three conditions have some features in common. All three types of diseases are characterized by a marked reduction of top growth and especially by the sudden appearance of green streaks on the stem and young petioles. *Bunchy-top* and *die-back* are almost always characterized by failure of latex flow on wounding affected tissues, whether of leaf, fruit or stem; but this phenomenon is much less common in the mosaic type of disease. Our efforts to transmit either bunchy-top or die-back by mechanical means have so far proved fruitless, but we have been more successful in handling the mosaic type.

This paper deals with the transmission of papaya mosaic, resembling the so called papaya mosaic type "B", reported by Acuña and De Zayas (1) from Cuba.

FIG. 2.—Left, diseased plant showing stuntiness and leaf deformation. Markers show filiform deformity of lamina. Right, healthy control.

MATERIALS AND METHODS

The virus material used in the different experiments came originally from a diseased papaya plant grafted with tissue from a mosaic infected plant brought to the laboratories from the Ponce-Guánica region.

All transmission experiments were conducted on healthy papaya plants grown in 6 inch pots in the greenhouse, ranging from 1½ to 3 months of age. Plants were taken to the laboratory and inoculated, using the pin-puncture method of Seín's (9), rubbing with carborundum, and grafting. In the pin-puncture technic, pieces of leaves, from infected plants showing early symptoms of the disease, were wrapped as closely as possible to the growing point and also about the middle of the stem and punctured repeatedly 1 to 15 times with an insect

needle. When the abrasive was used, an infected leaf was macerated in a mortar with a little sterile sand and water, the extracted juices were strained through cloth and the filtered

FIG. 3--Two plants showing atrophy of growth and leaf deformation.

juice applied with a cotton swab impregnated in the liquid, over one or two of the youngest leaves previously powdered with a little carborundum. Leaves were held in position with a clean wooden label.

In grafting, slips made with a razor blade from stems of infected plants showing oil streaks, were inserted into slits in the stem of the healthy stock, or slices from the cortical layers of healthy stem were taken and the infected slips firmly attached to it. In both cases, the grafts were covered with a piece of moist cotton and lightly tied with strings. The cotton was kept moist during the first few days by spraying with water from an atomizer.

All inoculated plants were kept in the laboratory from 4 to 5 days, then replanted into 10 inch. pots and taken to a wire screen shelter for further observations. Temperature inside

the shelter during the course of the experiment ranged from 74 to 90°F.

Controls were treated in the same manner, using materials from healthy plants for the different operations.

FIG. 4—Oily spots on stem of diseased plants.

TRANSMISSION

By pin punctures: Papaya mosaic was readily transmissible from diseased to healthy papayas by the use of a needle as described above. Eleven out of twenty-nine trees were infected by using this technic.

It was observed that, in general, the chances for a successful transmission were better if the leaves used as a source of inoculum were taken from the infected plant during the first two or three days after inception of the disease. Extracts made from leaves just beginning to show symptoms yielded a very infectious liquid.

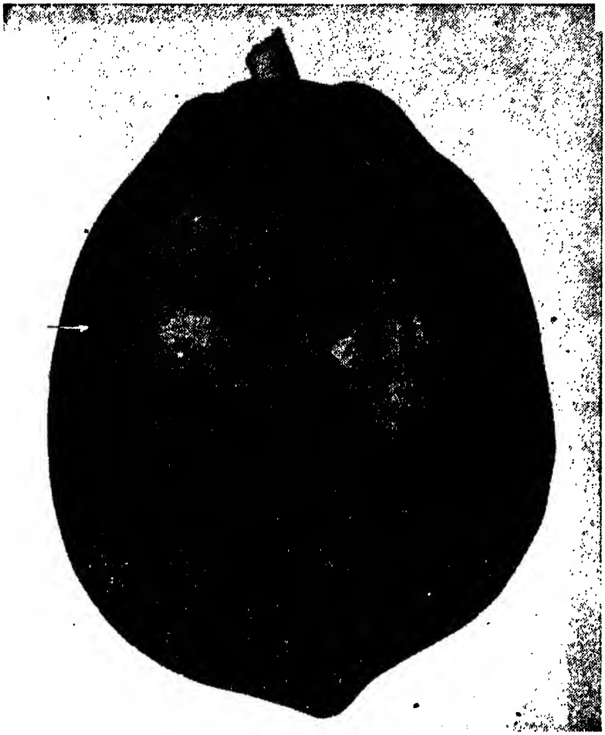

FIG. [illegible]—Fruit taken from a diseased tree. Notice sharp rings on the surface of the fruit.

By the use of carborundum: Transmission by means of an abrasive (carborundum) was also readily accomplished. We have found this method to be a much easier and more effective way of transmitting the disease than pin puncture. Positive results were obtained in twenty three out of twenty eight inoculations.

By grafting: Pieces of stem tissues from infected plants grafted on healthy plants, in the manner described under Methods, transmitted the disease.

SYMPTOMS

Plants inoculated either by pin puncture or carborundum developed symptoms in 8 to 15 days after inoculation. Grafted plants took from two to three weeks before showing any evidence of the disease.

Inoculated and grafted plants exhibited at first a slight chlorosis of top leaves, followed by mottling, wrinkling and puckering. A light yellowing of the veins was also noticeable at this stage. As the disease progressed there was a marked deformation (figs. 1-2-3) and reduction of the leaf lamina, which in the majority of cases acquired a filiform structure. Leaves fully formed before onset of the disease remained normal.

A few days after the appearance of the initial symptoms, more or less elongated streaks, dark green in color (fig. 4), began to form about the middle of the stem, progressing upward and finally covering the whole length of the shoot. In only a few plants were we able to notice the occurrence of the streaks simultaneously with the appearance of primary symptoms. Concomitant with all these manifestations there was a gradual inhibition of the apical growth ultimately leaving the plant badly stunted (figs. 2 and 3), with a few small short petioles and distorted leaves on top. Two other distinguishing features of this disease were the flow of latex on wounding any part of the plant and the presence of green and dark-brown rings on the fruits (fig. 5).

The symptoms described above are generally present in field-affected plants, but the distortion of the leaves and atrophy of growth are not as severe as under laboratory conditions. Whether this is due to the influence of the environment on the expression of the disease, the age of the plant when inoculated, or other factors, we cannot say at present.

Discussion

Proper consideration of the published works on the so-called "Papaya Mosaic" diseases show that, although all of them present certain symptoms in common with the mosaic described in this paper, they, nevertheless, vary in certain other respects.

The diseases described from Trinidad (2), Hawaii (8), Cuba (Mosaic type "A") (1) and Puerto Rico (6), share with our mosaic the presence of oily spots on the stem and petioles; and the marked stunting of growth with reduction in the size of the leaves, internodes and petioles. They differ, however, in not showing the characteristic mottling and extreme distortion of the leaf lamina, which is a prominent feature of our disease. The Trinidad mosaic is further differentiated by the

fact that, according to Baker, it is characterized by "a rapid die-back starting from the crown a few weeks after infection." On the other hand, the Trinidad, Hawaii, Puerto Rico and Cuba diseases present some symptoms in common, but the first is again differentiated from the last three by the rapid die-back of the crown.

There is, however, another disease reported from Cuba as mosaic of papaya (type "B") (1), which insofar as can be judged from its description, seems to be related, if not identical, with the mosaic under consideration. It is pertinent to state that in our opinion, the mosaic (type "B") from Cuba closely fits into the description we have just given of our own mosaic. Added weight for this assumption is supplied by a photograph of a distorted leaf, included in the paper just mentioned, which is indistinguishable from our own material. Unfortunately, the Cuban investigators were unable to transmit the disease mechanically, so that definite comparisons of both diseases under controlled laboratory conditions are still wanting.

Summary

A mosaic disease of papaya is reported; characterized by stunting, with accompanying reduction in size of internodes, leaves and petioles, oily spots on stem and petioles, marked mottling and distortion of leaves, uninterrupted latex flow, and dark-green to brown rings on fruits.

The disease is transmitted by pin puncture, rubbing with carborundum and stem grafting.

The similarities and differences in symptomatology between this disease and others of similar nature reported from other parts of the world, are presented.

The disease is, however, believed to be closely related to, if not identical with, the mosaic type "B" from Cuba.

Resumen

Se ha hecho relación de una enfermedad denominada "mosaico" de la papaya, la cual se caracteriza por un detenimiento en el desarrollo de la planta, acompañado de reducción en el tamaño de los internodios, hojas y pecíolos; manchas oleaginosas en los tallos y pecíolos; marcado moteado y torcimiento de las hojas; interrupción del flujo del látex y círculos verdinegros o color castaño en las frutas.

La enfermedad se transmite mediante punturas con agujas, frotaciones con carborundo e injertos en los tallos.

Se han dado a conocer las similitudes y diferencias en la sintomatología entre esta enfermedad y otras de naturaleza parecida, sobre las cuales se han recibido informes de otros sitios del mundo.

La enfermedad está, por lo tanto, de acuerdo con el criterio del autor, intimamente relacionada con el "mosaico" tipo "B" procedente de Cuba.

ACKNOWLEDGMENT

The author is deeply indebted to Dr. Francis O. Holmes, of The Rockefeller Institute for Medical Research at Princeton. without whose personal interest and unfailing advice this work would not have been accomplished.

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STUDIES ON VIRUS DISEASES OF PAPAYA (CARICA PAPAYA) IN PUERTO RICO [1]

II. Transmission of Papaya Mosaic by Green Citrus Aphid, (Aphis spiraecola Patch)

By José Adsuar [2]

As described in a recent paper (Adsuar 1945) a mosaic of papaya has been found attacking this crop in the southern coast of Puerto Rico. Although the disease has been transmitted both mechanically and by grafting, it was not until very recently that we have also successfully accomplished its transmission by means of the green citrus aphid, (*Aphis spiraecola* Patch).

This aphid, a major pest of citrus trees, in which it causes the well known "rosetting" of the leaves, seems to migrate to papayas during certain seasons of the year, at least under our tropical conditions. Originally described from material collected on spiraea, in Maine, it was first found in Puerto Rico on grapefruit in 1926. It was the fortunate coincidence of noting its presence on papayas during a routine inspection of our experimental plots, later confirmed for different sections of the island, including the southern coast, which led us to test its vector potentialities. This paper reports the experimental transmission of papaya mosaic by the green citrus aphid (*A. spiraecola* Patch).

Transmission Studies

Aphids, both nymphs or winged forms, were used in the different experiments. They were fed for periods varying from 8 min. to 1 hour on mottled leaves from papaya plants showing early symptoms of the disease and then transferred by means of a camel's hair brush to healthy plants about 3 months old caged in cellulose tube casings (Fig. 1). The number of aphids used for each transmission experiment varied from 6 to 10, but was never less than 6.

Controls were prepared by transferring aphids, handled in the same way, directly from citrus to healthy papaya plants.

[1] Published (June 1946) as Technical Paper No. 2 of the Agricultural Experiment Station, Río Piedras, P. R.
[2] Plant Pathologist, Agricultural Experiment Station, University of Puerto Rico.

Aphids collected from experimental plants showing definite symptoms of the disease were sent to Dr. P. W. Mason at Washington, who identified them as *A. spiraecola* Patch.

Results

Positive transmissions were obtained in 15 out of 33 plants subjected to the action of *A. spiraecola Patch* fed on diseased papaya leaves for periods of time varying from 8 min. to 1 hour. Both nymphs and winged adults transmitted the disease with equal ease. All controls remained healthy.

The evidence seems to indicate that the aphids are avirulent while on the citrus leaves and that if they are instrumental in the propagation of the disease in the field, they must acquire the virus later during their migration. Further work is still needed to elucidate, among other things, whether *A. spiraecola* Patch is the only vector involved, when and where it become infectious, modes and seasons of migration to papaya plantations, retention of virus by the insect, etc.

Resultados

Se ha verificado la transmisión del mosaico o moteado de la papaya en Puerto Rico, a través del áfido conocido por pulgón cítrico verde, *A. spiraecola* Patch.

Este áfido es el causante de la enfermedad denominada "encaracolado" de las hojas de los cítricos.

Se obtuvieron transmisiones positivas en 15 de 33 plantas sometidas a la acción del áfido *A. spiraecola* Patch que se alimentó en hojas de papayos enfermos durante períodos de tiempo que variaron de 8 minutos a una hora. Tanto las ninfas como los adultos alados transmitieron la enfermedad con igual facilidad. Todos los testigos sometidos a la acción de los áfidos alimentados en hojas sanas permanecieron libres de la enfermedad.

La evidencia parece indicar que los áfidos adquieren el virus durante el proceso de emigración hacia los papayos. Se hace necesario todavía continuar los experimentos para dejar claramente sentado, entre otras cosas, si el áfido *A. spiraecola* Patch es el único vector envuelto en la transmisión de la enfermedad, cuándo y dónde llega a ser infeccioso, el modo y la época de emigración a las plantaciones de papayos, la retención del virus por el insecto, etc.

ACKNOWLEDGMENT

The writer wishes to make grateful acknowledgment to Dr. G. N. Wolcott, Head of our Department of Entomology, for information and advice on this aphid and for securing the specific identification through Dr. P. W. Mason, Specialist in the Bureau of Entomology, U.S.D.A.

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FIG. 1.—Papaya plant illustrating cellulose tube used in the experiments.

STUDIES ON VIRUS DISEASES OF PAPAYA (CARICA PAPAYA) IN PUERTO RICO

III. Property Studies of Papaya Mosaic Virus

By José Adsuar [1]

During the last two years a couple of virus diseases (Adsuar, 1, 2) have been found attacking papaya *Carica papaya* in Puerto Rico. One of them, the so called "bunchy top" disease, is of general occurrence through the island and resembles in general appearance the papaya viroses reported from Trinidad, Cuba and Santo Domingo. "Bunchy top" is extremely difficult, if not impossible, to transmit either mechanically or by grafting, and it has been only recently that we have been able to obtain evidence of its transmission by means of a leafhopper vector (3). The other disease, a typical *mosaic*, differs from "bunchy top" not only symptomatologically, but also in the fact that it is easily transmissible by mechanical means as well as by grafting. Its insect vector is an aphid (2).

Due to its stability *in vitro* and to the ease of mechanical transmission, experiments were undertaken to determine the physical properties, filterability, etc., of the papaya mosaic virus.

Materials and Methods

The virus was obtained from artificially infected papaya plants kept inside wire-screened shelters. The plants were inoculated with the aid of carborundum following the method described by Adsuar (1). All experiments were conducted in sets of four plants each. After treatment the plants were transplanted into 12 inch pots and transferred to the shelters. The aphids used in the retention experiment were taken from papaya trees, starved, and then fed on infected leaves for the required periods of time, inside Petri dishes. After feeding was completed, they were removed and placed on healthy plants for the retention studies.

[1] Plant Pathologist, Agricultural Experiment Station, University of Puerto Rico.

EXPERIMENTAL STUDIES ON THE PAPAYA MOSAIC VIRUS

Resistance to Heat:

Leaves from recent cases of *mosaic* were pounded in a mortar with sterile sand and 1 cc. of distilled water gradually added. The juice was expressed through heavy muslin, and about 2 cc. of juice obtained. To these more water was added, making a final dilution of approximately 1:12. Samples were then heated in corked tubes holding about 1¼ cc. each, to temperatures of 50°C, 55°C and 60°C for 3, 10 and 30 minutes periods at each temperature. (Table I).

TABLE NO. I

THERMAL INACTIVATION OF PAPAYA MOSAIC

Temperature °C	Minutes heated	Number of Plants Inoc	Infected
50	3	4	4
50	10	4	4
50	30	4	4
55	3	4	4
55	10	4	1
55	30	4	0
60	3	4	0
60	10	4	0
60	30	4	0

The results indicated that papaya mosaic virus has a thermal inactivation range between 55°C to 60°C for 10 min. Exposures to 55°C for 10 min. show a decrease of infectivity, with complete inactivation at 60°C for the same period of time.

Tolerance to Dilution:

Infected leaves showing early symptoms were crushed in a mortar with a little sterile sand and distilled water, the pulp squeezed through muslin, and the resulting green fluid diluted as follows: 1:4; 1:16; 1:64; 1:256 and 1:1024.

The virus remained infective up to and including 1:256. No infections were obtained with the 1:1024 dilution.

Longevity in vitro at room temperature:

Samples obtained as above and diluted approximately 1:12 were stored at laboratory temperature (29°C) and tested at 24, 48 and 72 hrs. No fermentation or putrefaction was noted. Chlorophyll settled leaving a clear fluid above. Part of the same juice was put in the refrigerator at 10°C and tested at different intervals of time.

The results indicated that the virus is completely inactivated in 48 hrs. at room temperature. At refrigerator temperature, the virus was still active at the end of 15 days.

Filterability:

Leaves of plants showing the disease were ground with approximately three times their weight of distilled water. Juice was extracted through muslin and centrifuged for 15 minutes in a clinical centrifuge. To the supernatant fluid was added ¼ cc. of a 19 hr. culture of *Sarcina lutea* in broth (Difco). The mixture was then filtered through a Seitz disc No. 5114-C10.

The filtrate proved to be free from bacteria as determined by inoculation in sterile nutrient broth and on nutrient agar slants. The virus passed the filter, but apparently did so with much difficulty. Of our plants inoculated, only one came down with symptoms. Controls inoculated with the unfiltered mixture all showed the disease.

Inactivation by Drying:

Recently affected young leaves (showing vein clearing and chlorotic spotting) from previously inoculated plants were picked, tied together and suspended in a shady but breezy part of the laboratory for drying. Some of the leaves were macerated immediately after collection with the addition of 2 cc. of water and the juice tested for infectivity. The rest of the leaves were allowed to dry for 48 hours and 72 hours periods. Samples extracted as explained above were obtained at the required time and inoculated on healthy plants. Plants inoculated with juice from leaves extracted immediately after picking all came down with the disease. None of the plants inoculated with juice extracted from leaves air dried from 48 to 72 hours became infected.

Retention of Virus by Aphids:

Winged adults of *Aphis spiraecola* Patch were collected and starved for about 1 hour, transfered to infected leaves, and allowed to feed for 15 minutes. Aphis in lots of five were then taken to individual papaya seedling and allowed to feed for 3 hours. After that interval they were removed to new seedlings. Table 2 shows the result of the experiment.

TABLE No. 2

RETENTION OF PAPAYA MOSAIC BY *Aphis Spiraecola* PATCH

Lot	Number Aphids Used	Plants inoculated during 3 hrs. period	Plants infected during 3 hrs. period	Plants inoculated after 3 hrs. period	Plants infected after 3 hrs. period
1	5	1	1	1	0
2	5	1	1	1	0
3	5	1	1	1	0
4	5	1	0	1	0

The results demonstrated that the aphids failed to retain the virus for more than 3 hours.

SUMMARY

The physical properties of papaya mosaic virus are reported. The virus is inactivated by a 10-minute exposure at 60°C. No infection was obtained when juice was diluted up to 1:1000. The virus was completely inactivated in 48 hours at room temperature. Filterability was accomplished but with difficulty through a Seitz germicide filter. The virus was found to lose its infectivity in the leaves when air dried for 48 hours.

Aphis spiraecola Patch retained the virus the first 3 hours but failed to infect a second lot of plants after that time.

RESUMEN

Se ha informado sobre las propiedades físicas del virus del mosaico de la papaya. El virus queda inactivo, mediante una exposición a 60°C durante 10 minutos. No se obtuvo infección alguna cuando el jugo fué diluído hasta 1:1000. El virus queda competamente inactivo en el término de 48 horas a la temperatura del laboratorio. Se efectuó con dificultad la filtración a través de un filtro tipo Seitz No. 5114-C10. Se descubrió que el virus perdió su infectividad en las hojas expuestas al aire durante 48 horas.

El afídido *A. spiraecola* Patch retuvo el virus durante las primeras tres horas; pero, después de ese tiempo, no logró infectar un segundo número de plantas.

ACKNOWLEDGMENT

The writer again wishes to acknowledge his gratitude to Dr. Francis O. Holmes of the Rockefeller Institute at Princeton, New Jersey, for his disinterested and helpful collaboration in carrying on this work.

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COMPARATIVE PERFORMANCE OF THE NATIVE PUERTO RICAN FOWL, THE WHITE LEGHORN, THE NEW HAMPSHIRE, AND CROSSES BETWEEN THEM

A. GONZÁLEZ CHAPEL [1]

INTRODUCTION

The problem of Puerto Rico is mainly an increasing population without a corresponding increase in production. The population of the Island in 1940 was around 2,000,000 inhabitants The Island has an area of about 3,435 square miles and there were approximately 605 inhabitants per square mile of territory. During 1946 there was a rate of natural increase of 29.6 per 1,000 population, which is one of the highest birth rates of any country in the world. Thus, the population in the Island is increasing at a rate of approximately 60,000 people every year.

The people of the Island are largely dependent, directly or indirectly, upon importations from the United States for their foods from animal sources. The importations of livestock products and livestock feeds were near $50,000,000 during the fiscal year 1947–48. The following table shows the yearly per capita supply in Puerto Rico in 1939–40 of the main foods containing animal protein as compared with an adequate diet at minimum cost as given by the Bureau of Home Economics of the United States Department of Agriculture (1933). In addition, the per cent of the supply that was imported during that year is also given.

Item	Annual per capita supply in P. R.	Per Cent imported	Amounts for one person in adequate diet at minimum cost
Fresh milk	54 qts[1]	0	260 qts.
Meat, poultry and fish	53 lbs.	56	60 lbs
Eggs	4 doz.	13	15 doz.

There are potentialities for considerable expansion of the livestock industry in the Island.

[1] Associate Animal Husbandman.

Poultry products are one of the chief foods in Puerto Rico. In 1935, the farm value of poultry products (meats and eggs) ranked sixth in importance among the various sources of income on farms in Puerto Rico. This value was distributed almost equally between meat and eggs. There is reason to believe that no essential change in the situation has occurred.

According to the census of 1940, the poultry population of the Island was 1,751,292.

During the fiscal year 1945–46, shipment of poultry and poultry products from the United States amounted to $1,362,010. These shipments were distributed as follows:

Item	Amount	Value
Poultry, live	201•087	$256,632
Chicken	5,453 lbs	5,462
Poultry and game fresh, not canned	737,851 lbs	291,420
Eggs, in the shell	1,589,942 doz.	671,189
Egg albumen, frozen, dried or otherwise preserved	17,068 lbs.	4,973
Other egg products dried, frozen or otherwise preserved	379,583 lbs.	132,334
		$1,362,010

Data on milk, not fresh, were not available.

During the fiscal year 1947–48 the value of these shipments was probably close to $3,000,000.

If the productive capacity of the poultry were increased, Puerto Rico could not only be made more self-sufficient in regard to the present demands for poultry products, but also the nutrition of the people could be improved by increasing the consumption of the foods supplying animal proteins. The diets of Puerto Ricans are, as a rule, woefully lacking in such foods.

The Problem

The apparent obstacles to the expansion of the poultry industry in Puerto Rico are the assumed poor productivity of the native breed, the high cost of the feed, the poor management practices, and parasites and diseases.

The development of a well adapted breed with better productivity than the native would be a first step toward the development of the poultry industry and an important contribution to the Island's economy.

The native fowl is the product of interbreeding different breeds and strains, without uniformity in feather color, light in weight, and supposedly with low productive capacity and much resistance to diseases. It has also been assumed that the native

fowl is adapted to the Island's environment and to the living conditions of the small farmers. No systematic study has been made in the past of the bird's productive capacity.

The native birds, receiving very little care and attention from the farmers, constitute an almost free source of income in the small farms of the Island. It is logical to suppose, however, that during the many generations of their existence in Puerto Rico, natural selection and some unconscious human selection could have favored development of adaptability to the general conditions in Puerto Rico.

A few flocks of imported breeds are kept by some farmers in the Island, but they are kept under conditions beyond the means of the average Puerto Rican farmer. Scant or no information about the productivity of most of these flocks is available. In the past it has been assumed that the imported breeds in Puerto Rico have laid well and developed to good size, but that they were very susceptible to disease and unadapted to the environment on farms.

Rhoad (1941, p. 512) stated,

> Farm animals are kept for the most part in an environment that it is in many ways artificial, man created. Much of the success of the livestock industry depends upon our ability to furnish a favorable environment in which livestock can develop and produce to the limit of their inherent capacities. To the extent that this cannot be done economically, it is necessary to select and modify breeds to fit the natural environment, of which climate is a major part.

A study of the productive capacity of the native fowl in comparison with that of standard breeds reared under similar conditions and studies of an exploratory nature on the possibilities of crosses between the native and standard breeds seem logically the first step to follow.

Thus, the objectives of this study were to find out any practical differences between the native fowl and the standard breeds in Puerto Rico in respect to their productive capacity; if differences were apparent, to determine which breeds were the best in the different characters considered; and to determine the performance of crosses of the native with the standard breeds.

Review of Literature

The average temperature in Puerto Rico is somewhat lower and more uniform than in other places in the tropics located at

the same latitude. The mean annual temperature for the Island is around 76°, varying in different places according to the elevation and topography.

In the tropics, unlike in temperate climates, the average monthly temperature is subject to small variation during the year, but marked differences in temperature occur within the day period. The highest temperature occurs generally around noon and the lowest in the early morning.

The average minimum annual temperature for the Island is 66.9° and the average maximum annual temperature is 86°. At Aibonito, where the livestock production farm of the Agricultural Experiment Station is located, the lowest temperature recorded is 40° and the highest 92° (Harris, 1947).

Records of rainfall in Puerto Rico (Thorp, 1941) indicate an average maximum annual precipitation of 136 inches and a minimum of 27 inches. Because of the high mean temperatures, the effectiveness of the rainfall is considerably less than it would be in cooler climates, and it is further reduced below that of many cooler regions because of the almost constant air movement.

Humidity is nearly always high. In some parts of the Island it is over 75 per cent most of the time.

The effect of climate and the external environment upon humans and animals have been studied extensively in the last few years. Lush (1945) pointed out that this interest arises mainly from tropical and subtropical regions for which none of the established breeds of animals seem well suited.

Observations made on human beings tend to indicate a lowered basal metabolism in the people of the tropics as stated by Mukherjee and Gupta (1931) and Sherman (1941). Heinbecker (1928), on the other hand, found that the basal metabolic rate of 3 Eskimos was 33 per cent greater than standards for subjects in the temperate zone. Mason (1940) found that 13 out of 21 English and American women who changed their residence from temperate to tropical climate showed a distinct fall of metabolic rate in the tropics, averaging approximately 10 per cent. In a study of basal metabolism as affected by atmospheric conditions McConnell (1925) concluded that the zone of minimum metabolic rate was between 75° and 83° effective temperature. Roddis and Cooper (1926) found in 173 naval officers in the tropics that blood pressure was reduced 10–15 mm. Hg. below textbook standards.

On animals the literature is more extensive and shows, as in human beings, the definite effect of the external environment upon their physiological responses.

The resistance of animals to cold is much greater than that to heat, according to Brody (1940) who also concluded that the thermoneutrality zone varies with the season, and the temperature to which the animal is acclimatized, but the maximum temperature is about 85°F.

Regan and Richardson (1938) found that increasing the room temperature caused an increase in respiration rate of dairy cattle, a decrease in pulse rate, and after 80°F. a rise in body temperature, anorexia and a decline in milk flow. Rhoad (1942) tested more than 150 cows, heifers and steers of the Iberia Livestock Experiment Farm, in Jeanerette, Louisiana, for adaptability to tropical climatic conditions and claimed that as a result the variously bred types of cattle in the Jeanerette herds can be classified from the most adaptable to the least adaptable type. The same author (1936) suggested that the loss of energy in dairy cattle as a result of high temperature is in a large way responsible for the low production records of European dairy cattle in the tropics. Forbes et al. (1926) found that the per cent of heat emission as latent heat of water vapor increased with an increase in temperature. Manresa and Orig (1941) implied that the ability to withstand external heat without significantly raising the temperature of the body might be used as a test for adaptability of different breeds of cattle to a given environment. Gaalaas (1947), in a study of Jersey cows, found that the heat-tolerance coefficient was a reasonably stable individual characteristic at ages of 4 years and above, but not at 2 or 3 years of age. Seath (1947) concluded that body temperature appears to be a safer measuring stick for heat-tolerance than does respiration rate.

Lee and Robinson (1941) found that the sheep is outstanding among domestic animals in tolerating hot atmospheres, withstanding for 7 hours a temperature of 110°F. with 65 per cent humidity. Lee, Robinson and Hines (1941) concluded that the tolerance of the rabbit resembles that of the fowl and that seasonal variations were complex and important. Robinson and Lee (1941 a) found that the cat shows far less reaction to heat than the fowl, rabbit or pig. Temperatures of 105°F. cannot be tolerated if the humidity is above 65 per cent. The same authors (1941 b) found that the tolerance of the dog to hot

atmospheres is slightly greater than that of the cat. The effect of humidity was marked. They also found (1941 c) that the tolerance of the pig for hot atmospheres resembles that of the fowl and the rabbit. Humidity was important at high temperatures but not at intermediate temperatures. Unlike the fowl and the rabbit, the pig's reactions to heat was noted to include a definite rise in pulse rate.

Marshal (1937) stated that Southdown ewes and red deer transported from the northern hemisphere to Australia, South Africa and the Argentine reverse their breeding season in about two years to conform with the conditions in the new habitat. New Zealand kinds introduced into England make the reverse adjustment in the same time. Similar adjustments are made by fallow deer, moose, wapiti and chamois introduced into New Zealand. Parakeets from Southern and Central Australia adjust themselves to English conditions, but those from Northern Australia retain their original breeding season.

Asmundson and Lloyd (1936) concluded that lower outside temperatures, particularly during the first few weeks, appeared to result in increased rate of growth of turkeys. Humidity did not apparently affected growth although continuous rain retarded growth.

Yeates, Lee and Hines (1941) found that a rectal temperature of 113° F. is the highest the fowl can reach before developing heat stroke. White Leghorns can withstand heat better than Australorps. Barott and Pringle (1941), in a study of metabolic rate of the Rhode Island Red hen, for a temperature range of 50° to 95°F., found that a point of flexure occurs at 78°F. They concluded that this is the temperature of minimum metabolism of the hen. The maximum metabolism occurred at 61°F., at which temperature there was also a point of flexure. The rate of elimination of respiratory water was approximately constant between 65° and 75°F. The rate decreased considerbly between 60° and 50°F. The rate at 90°F. was three times that at 80°F. This was due to the large amount of air inhaled and exhaled for cooling at the high temperature. It was found that hens at a given temperature would survive at the lower humidities but would die when the humidity was increased. Bennion and Warren (1933) found that extremely high or low temperatures were followed by a decline in production; birds were more sensitive to sudden temperature changes. They also stated that in comparing egg size of birds from different parts

of the United States, the temperature and its effects on egg size should be taken into consideration. They found that the mean weekly egg weight when compared with the mean maximum weekly temperature showed a sharp decline when the temperature was above 85°F. The mean daily egg size of birds placed under controlled temperature was reduced from 15 to 20 per cent by application of high temperatures. The egg size declined much more rapidly under high temperature than it increased when the temperature was lowered. All components of the egg decreased under high temperature. The shell and albumen decreased considerably more than the yolk in proportion to their weight, which indicates that the oviduct is more sensitive than the ovary to high temperatures. Warren (1939) secured data on egg size from 11 localities in latitudes extending from the Equator to as far north as Scotland and concluded that excessively low temperatures seemed to have no effect on egg size, but after the daily maximum temperatures exceeded 70°F. for a period of a few days, egg size fluctuations usually showed a close correlation with those of temperature. Lorenz and Almquist (1936) found evidence of a decrease in egg weight proportional to the increase in temperature between 40° and 90°. Burrows and Byerly (1938) found that temperatures above 90°F. was one of the factors that increased broodiness. Hays and Sanborn (1939) found that fertility in Rhode Island Red females varied with the temperature. As the temperature rose from, on the average, about 16°F. to 46°F. the fertility increased. However, Lamoreux (1943) found in White Leghorns no relationship between outside mean temperature and the proportions of eggs laid that were infertile. Mean weekly temperatures ranged from 22.9°F. to 50.1°F. In both of these studies the highest temperature tested was 50.1°F. Kempster (1938), at Missouri, found that high maximum temperature that prevails during the summer retards the growth of pullets.

Warren (1930) found that disturbances that are sufficient to cause a decrease in the daily production of a group of White Leghorn pullets affect the rhythm of egg production. Bissonnette (1933) pointed out that in other birds sexual cycles are directly modifiable by changes in the daily exposure to light. French (1940) found that there appeared to be some relationship between hours of sunlight and egg production but the relationship to temperature was not so definite. Resananda,

(1924) in a study of the best season for hatching eggs in the Philippines using eggs from several imported and Asiatic native breeds concluded that humidity and wind velocity had little effect. Wetham (1933) stated that the natural variation in daily light period at different latitudes has been used to study the effect of light on egg production throughout the world. There was a decided apparent correlation between egg production and the hours of daylight but the egg production curve precedes that of the light. It appeared that, where the hours of daylight are distributed more evenly throughout the year, the egg production is more evenly distributed throughout the year. Mann (1941) reported that the wet season in Malaya causes a decreased fecundity in Rhode Island Reds, increases incidence of the molt, and increases mortality. Hutt (1938) reported that during six days of heat at Ithaca, New York, when maximum temperatures reached 101, 103, and 102°F. on three successive days, the deaths from heat prostration were 1.79 per cent in White Leghorns, 5.26 per cent in Rhode Island Reds, and 5.16 per cent in Barred Rocks. He concluded that the genetic constitution of the White Leghorn appears to give that breed more control over its thermo-regulatory processes than is available to the other breeds compared with it.

The evidence on effect of high temperature and especially high humidity as reported in humans, cattle, other animals and poultry indicates that the physiological response of animals and poultry to tropical and subtropical climates is different to that of temperate and cold climates.

It is probable that different standard breeds of poultry may react differently in adaptability to the climate and general environment of Puerto Rico. Many workers have found definite differences between breeds in response to certain stimuli under certain specific conditions. Taylor and Martin (1928) concluded that their Barred Rocks strain laid eggs with a significantly lower per cent of shell than a strain of White Leghorns. Morgan (1932) found that the Barred Plymouth Rock eggs require less weight to crush the shells than the White Leghorns. Hyre and Hall (1932) stated that hatching power seems to be more constant in the Single Comb White Leghorns studied than in the heavy breeds. Harris and Boughton (1928) found that the Rhode Island Red breed shows a somewhat higher death rate

than the White Leghorn breed although that conclusion was questioned by Dudley, (1928). Lambert (1935) stated that heritable differences in resistance to infectious diseases exist and that non-infectious diseases are largely, in most cases, a genetic problem. Longevity and strong constitution were considered as inborn traits of certain families and strains. Roberts and Card (1926) concluded that it may be possible to establish a strain of fowls that would be highly resistant to infection with *S. pullora*. Serfontine and Payne, cited by Jull (1946), observed that White Leghorns were more resistant than heavier breeds to Perosis or slipped tendons. Pappenheimer, Dunn and Cone, cited by Jull (1946), stated that their observations indicated a very significant breed or variety difference in susceptibility to paralysis. Lamoreux and Hutt (1939) found that ability of White Leghorn chicks to survive on a diet deficient, or lacking, in vitamin B_1 was greater than that of the Rhode Island Reds. Hutt (1935) demonstrated a breed difference between White Leghorns and Rhode Island Reds in the rate at which body temperature rises during the first nine days after hatching.

Crossing breeds for the purpose of developing better breeds for tropical climates is being done with cattle and other animals in different parts of the world. Bray (1932) found that a Brahman cross on native and grade beef cattle in southern Louisiana was valuable because it withstands heat and is less affected by flies, mosquitoes and external and internal parasites. Also this cross was observed to make good gains on grass alone. Rhoad (1938), in a study of the response of pure-bred *Bos taurus* and *Bos indicus* cattle and their crossbred types to certain conditions of the environment, found that high atmospheric temperatures and humidity influence, in unlike manner, the respiration rate and body temperature of typical *Bos taurus* and *Bos indicus* cattle. The same author (1940) determined that the purebred and three-quarter bred Aberdeen Angus are not physiologically adapted to the high temperature and intense solar radiations characteristic of tropical climates. On the other hand, he stated that the efficiency with which the purebred and half-bred Brahman regulates body temperature in the same environment is evidence that tropical climatic conditions are within the range of neutrality for these cattle. This indicates, therefore, that these cattle are physiologically adapted to a tropical

environment. According to Rhoad, the differences in the physiological responses of these cattle to tropical climatic conditions are genetic in origin. Rhoad (1935, p. 214) stated:

> The general conclusion reached in all parts of the tropical world, however, is that the permanent solution of the farm dairy problem is not devising new ways of managing the old established breeds, but rather the development of new breeds using the native type as foundation stock.

The same author (1941, p. 512) stated that there are distinct differences between species and breeds in their ability to withstand climatic conditions. He said,

> It has been clearly demonstrated in recent years, that the lack of adaptability of certain types of animals to tropical climatic conditions, as evidenced by discomfort, low production, and frequently degeneration in type, can best be overcome by breeding.

Crossbreeding of Brahman with standard beef breeds for resistance to subtropical climatic conditions has been, according to Rhoad, a general practice in the Gulf-coast region for more than a generation. From one of these crosses, the Shorthorn x Brahman, there has evolved the first strictly American breed of beef cattle, the Santa Gertrudis, developed by the Klebergs of the King Ranch, Kingsville, Texas. Improved dairy types of cattle adaptable to tropical and subtropical climatic conditions are being developed in India with pure Brahman (Zebu) stock, while in Brazil, Jamaica, and the Philippines new Brahman-European crossbred types are appearing. In the Philippines a new breed of swine, the Berkjala, a cross between the Berkshire and the native Jalajala, is being developed as a lard type hog adapted to tropical climatic conditions. At the Agricultural Experiment Station of the University of Puerto Rico breeding projects are now in progress for the development of better adapted breeds of cattle, swine, goats, and poultry.

Results obtained in crossing poultry breeds have been reported by some workers in the United States.

From crosses between Single Comb White Leghorns and Jersey Black Giants Warren (1926, 1927) found that the F_1 crossbreds hatch better, grow faster and lay better than do the parental breeds. They also showed a lower mortality. The viability of the crossbred chicks to three weeks of age was superior to that of the White Leghorn and Jersey Black Giant purebred chicks. The adult size of the crossbreds was inter-

mediate between that of the two breeds crossed. Byerly, Knox and Jull (1934) stated that crossing breeds is likely to increase hatchability by decreasing mortality during the third week of incubation. Knox, cited by Jull (1946), observed that crossbred progeny obtained from several different crosses, on the average, had 13.3 per cent better viability than purebred progeny, viability being measured from hatching time to the end of the first laying year. Jull (1946, p. 227) summarized the effect of crossing breeds on body size as follows:

> In practically all cases in which there was not an extreme difference in size between the parental breeds that were used in the original cross, the size of the F_1 progeny was about midway between the parental breeds or slightly nearer the larger breed. In those cases in which there were extreme differences in size between the parental breeds crossed, as in the case of the Barred Plymouth Rock x Rose-Comb Bantam matings made by Jull and Quinn (1931) and the light Brahma x Golden Sebright Bantam matings made by Maw (1935), the size of the F_1 progeny was slightly nearer the smaller sized breed.

In summary, the literature cited indicates that the high temperatures of tropical and subtropical regions lower the productivity of non-adapted animals including poultry, by reduction of the metabolic rate, and by other unknown causes. High humidity may aggravate the detrimental effect of high temperature on productivity. In poultry, egg size, broodiness, fertility, growth, hatchability, and egg production may be influenced. The literature cited also indicates that it is possible to find a differential response of the different breeds of poultry to the tropical environment. Crossing standard breeds with native stocks appear to be a definite possibility for obtaining adaptability together with relatively high productivity.

METHODS OF PROCEDURE

This study includes data collected from July, 1946 to June, 1948. The standard breeds were the New Hampshire and the Single Comb White Leghorn, that is, a representative each of the dual purpose and light egg types. These birds came from stock originally imported from the United States in 1940. Since that time they have been bred without any special selection.

The Native flock was obtained through purchases of birds throughout different parts of the Island in an attempt to make it a representative sample of the Island's stock.

Crossing the White Leghorn and the New Hampshire with the Native was started in 1945 but the numbers have been small up to 1947. Even then all crosses of White Leghorn x Native were combined and treated collectively. The same was done with all crosses of New Hampshire x Native.

The eggs from the three principal breeds and from the crosses between them were all hatched in the same incubator; the same feed was given all the birds, and they were reared in the same brooder house. The laying hens were confined to wire floor pens, 20' x 10', exactly alike and close together in an area of less than one acre. The same men took care of all the breeds.

In 1946 the hatching season extended from February 6 to June 6 for a period of four months. Chicks were hatched every week during that time but for statistical analysis they were divided, according to the date hatched, into six groups of three consecutive hatches per group. In 1947 the hatching season extended for a period of two months, from February 6 to April 4. Birds were again grouped according to date of hatch into groups, with three consecutive hatches per group. In 1947 there were only three groups.

A considerable amount of data was recorded on these birds but this study will be concerned only with egg production, sexual maturity, egg weight, body weight up to four months of age, and mortality. Except for mortality, the data in 1946 included 67 White Leghorn birds, 98 New Hampshire, and 39 Natives. In 1947, there were 68 White Leghorns, 165 New Hampshires, 33 Native, 69 White Legborn x Native, and 55 New Hampshire x Native. Chick mortality was recorded in 1946 on 145 New Hampshire chicks, 135 White Leghorns, and 121 Natives. For 1947 there were 616 New Hampshire chicks, 220 White Leghorns, 288 Natives, 493 White Lebhorn x Natives, and 665 New Hampshire x Natives. Laying flock mortality was recorded in 1946 on 137 New Hampshire hens, 91 White Leghorns, and 58 Natives. For 1947 there were 219 New Hampshires, 64 White Leghorns, 44 Natives, 122 White Leghorn x Natives, and 111 New Hampshires x Natives.

Egg production was measured on the basis of the number of eggs laid for the first 120 days of laying. Harris (1922), Thompson (1933), and many other workers, have shown that rate of production is a good criterion of total first year production.

Sexual maturity was measured as the age in days of the bird at first egg.

Egg weight per individual hen was measured in ounces per dozen eggs equivalent for the first 120 days of laying. Jull and Godfrey (1933), and other workers, have demonstrated the reliability of short periods egg weight records for estimating mean annual egg weight.

Body weight was taken in pounds at the end of the first, second, third, and fourth month of age. Funk, Knandel, and Callenbach (1930) found that initial chick weights and subsequent weights showed little correlation but that weights at 4, 8, 16, and 24 weeks show a high positive correlation with each other.

Chick mortality was measured as the percentage of chicks dead from hatching to one month of age. Dunn (1922) measured chick mortality to three weeks after hatching and stated that it seems probable that early chick mortality is the result of general constitutional weakness.

Laying flock mortality was recorded from the start of laying until each bird completed one year of production. Pearl (1923) stated that the individual which is structurally and functionally of superior constitution will, in the long run, exhibit a relatively high degree of longevity.

The method of fitting constants as given in Snedecor's text (1946) was used for analysis of variance of egg production, sexual maturity, egg weight and body weight. The t tests were carried out as given by Goulden (1939). The method of Patterson (1946) was also tried for the evaluation of interactions. Differences in mortality were tested through Chi-square analysis.

In all tables one asterisk (*) and two asterisks (**) represent statistical significance at the $P < .05$ and $P < .01$ levels of probability, respectively.

EXPERIMENTAL RESULTS

Comparison of White Leghorn, New Hampshire, and Native Birds

Egg production

In table 1 the average production of the three breeds for the first 120 days of laying during 1946 and 1947 is presented. The analysis of variance of these data is also given in this table.

The average egg production of the imported breeds is shown to be very similar with 45.5 eggs for the Leghorns and 47.6 eggs for the New Hampshires. However, the production of the Natives was only 26.4 eggs which is significantly lower than that of the other two breeds. This difference is shown for each of the two years.

In 1946 differences between hatches were significant. Birds hatched from February 6 to March 14 were the poorest layers and those hatched from March 21 to April 25 were the best layers. Interaction was, however, negligible, indicating that the date of hatch affected the production of the different breeds proportionally. The shortening of the hatching season during 1947, from four to two months, was effective in eliminating any important difference due to hatch. In tables 2 and 3 the effect of date of hatch on production during 1946 and 1947, respectively, is shown. The analyses of variance of these data are also given in the tables.

TABLE No. 1

MEAN EGG PRODUCTION OF WHITE LEGHORNS, NEW HAMPSHIRES, AND NATIVES DURING 1946 AND 1947

Breed	Mean Egg Production					
	1946		1947		Combined Years	
White Leghorn	(67)[1]	45.4	(68)	45.7	(135)	45.5
New Hampshire	(98)	47.5	(165)	47.8	(263)	47.6
Native	(39)	30.9	(33)	21.2	(72)	26.4
Unweighted mean		41.3		38.2		39.8

	Analysis of Variance		
	d/f	Sums of Squares	Mean Square
Years	1	176.51	176.51
Breeds	2	26,207.34	13,022.55**
Years and Breeds	2	1,503.42	751.71
Individuals	464	181,195.69	390.51
			b=19.75

[1] Figures in parenthesis are number of birds.

TABLE NO. 2

MEAN EGG PRODUCTION BY HATCHES OF WHITE LEGHORNS NEW HAMPSHIRES, AND NATIVES DURING 1946

Hatch	Mean Egg Production					
	White Leghorn		New Hampshire		Native	
1.	(14)[1]	41.1	(13)	23.9	(5)	23.2
2.	(7)	36.6	(16)	46.4	(3)	27.0
3.	(14)	38.2	(21)	49.8	(8)	40.8
4.	(19)	55.1	(32)	53.8	(13)	31.8
5.	(7)	46.0	(6)	49.7	(4)	27.5
6.	(6)	50.7	(10)	53.3	(6)	26.2
Average	(67)	45.4	(98)	47.5	(39)	30.9

	Analysis of Variance		
	d/f	Sums of Squares	Mean Square
Breeds	2	8,789.18	4,394.59**
Hatches	5	8,164.79	1,632.96**
Interaction	10	5,586.05	558.61
Individuals	186	62,209.89	334.46
			b=18.30

[1] Figures in parenthesis are number of birds.

TABLE NO. 3

MEAN EGG PRODUCTION BY HATCHES OF WHITE LEGHORNS, NEW HAMPSHIRES, AND NATIVES DURING 1947

Hatch	Mean Egg Production					
	White Leghorn		New Hampshire		Native	
1.	(11)[1]	43.6	(34)	49.0	(10)	17.5
2.	(25)	43.0	(39)	42.3	(13)	25.7
3.	(32)	48.7	(92)	49.6	(10)	19.0
Average	(68)	45.7	(165)	47.8	(33)	21.2

	Analysis of Variance		
	d/f	Sums of Squares	Mean Square
Breeds	2	17,969.54	8,984.77**
Hatches	2	1,150.45	575.22
Inte action	4	1,352.52	338.13
Individuals	257	102,731.99	399.74
			b=19.99

[1] Figures in parenthesis are number of birds.

Sexual maturity

In table 4 the average sexual maturity (age in days at first egg) of the three breeds during 1946 and 1947 is presented together with the analysis of variance.

The variation in the sexual maturity of the Native birds was considerable from 1946 to 1947. They were as late maturing as the New Hampshires in 1946 and as early as the White Leghorns in 1947. The White Leghorns had earlier sexual maturity than the New Hampshires in both years.

The standard deviation in sexual maturity during 1946 were 13, 38, and 44 days, respectively, for the White Leghorns, New Hampshires, and Natives. In 1947 it was 23, 41, and 52 days, respectively. There was less variation within the Leghorn birds than within the other breeds in respect to this trait. The wide variation within the New Hampshires and the Natives may account in part for the fairly large variance obtained from the residual individuals.

The date of hatch affected the sexual maturity of the birds of the different breeds differently during 1946. Earlier hatched birds of the White Leghorn and New Hampshire breeds, hatched during February 6 to February 21, had the earliest sexual maturity. The latest maturing birds of the New Hampshire breed were those hatched from May 2 to June 6 and of the White Leghorn, those hatched from May 23 to June 6. The earliest maturing Native pullets were those hatched from May 23 to June 6 and from February 6 to February 21. The latest maturing were those hatched from March 21 to April 4. Table 5 shows the effect of date of hatch on sexual maturity during 1946.

The shortening of the hatching season in 1947 was effective in eliminating the differences due to interaction of breeds x hatches. However, the tendency of the birds of all breeds was to mature earlier when hatched earlier. In table 6 the effect of date of hatch on sexual maturity during 1947 is shown together with the analysis of variance.

Egg weight

The average egg weight of the three breeds and the corresponding analysis of variance is given in table 7.

TABLE No. 4

AGE AT FIRST EGG OF WHITE LEGHORNS, NEW HAMPSHIRES, AND NATIVES

BREED	AGE AT FIRST EGG (days)					
	1946		1947		Combined Years	
White Leghorns	(67)[1]	187	(68)	192	(135)	190
New Hampshires	(98)	220	(165)	225	(263)	223
Natives	(39)	234	(33)	195	(72)	216
Unweighted mean		214		204		210

	ANALYSIS OF VARIANCE		
	d/f	Sums of Squares	Mean Square
Years	1	393.41	393.41
Breeds	2	99,291.99	49,646.00**
Years x Breeds	2	29,638.53	14,819.27**
Individuals	464	634,218.40	1,366.85
			b=36.97

[1] Figures in parenthesis are number of birds.

TABLE No. 5

AGE AT FIRST EGG BY HATCHES OF WHITE LEGHORNS, NEW HAMPSHIRES, AND NATIVES DURING 1946

HATCH	AGE AT FIRST EGG (days)					
	White Leghorn		New Hampshire		Native	
1	(14)[1]	175	(13)	187	(5)	211
2	(7)	197	(16)	217	(3)	222
3	(14)	186	(21)	210	(8)	265
4	(19)	185	(32)	224	(13)	242
5	(7)	190	(6)	262	(4)	236
6	(6)	213	(10)	245	(6)	202
Average	(67)	187	(98)	220	(39)	234

	ANALYSIS OF VARIANCE		
	d/f	Sums of Squares	Mean Square
Breeds	2	59,433.01	29,716.51**
Hatches	5	23,747.76	4,749.55**
Interaction	10	34,344.58	3,434.46**
Individuals	186	173,874.14	934.81
			b=30.57

Figures in parenthesis are number of birds.

TABLE No. 6

AGE AT FIRST EGG BY HATCHES OF WHITE LEGHORNS, NEW HAMPSHIRES, AND NATIVES DURING 1947

Hatch	Age at First Egg					
	White Leghorn		New Hampshire		Native	
1	(11)[1]	184	(34)	218	(10)	183
2	(25)	189	(39)	218	(13)	191
3	(32)	198	(92)	230	(10)	212
Average	(68)	192	(165)	225	(33)	195

	Analysis of Variance		
	d/f	Sums of Squares	Mean Square
Breeds	2	55, 149. 66	27, 574. 83**
Hatches	2	11, 399. 67	5, 699. 84*
Interaction	4	1, 472. 76	368. 19
Individuals	257	389, 373. 49	1, 515. 07
			t=38. 92

[1] Figures in parenthesis are number of birds.

Egg size was smaller for all the breeds during 1947 than during 1946. As a breed the New Hampshires had the largest eggs while the White Leghorn eggs were larger than the Native eggs.

There were significant differences between the hatches in both years but all breeds were affected proportionally by the date of hatch. During 1946 egg weight fluctuated up and down throughout the hatching season. During 1947 the tendency of the birds of all breeds was to have larger egg weight when hatched latest. This may be explained by the fact that late hatched birds in 1947 matured later and thus were older when they started laying.

The effect of date of hatch on egg weight during 1946 and 1947 is shown in tables 8 and 9 respectively.

The correlation between sexual maturity and egg weight can be observed easily by comparing table 8 with table 5. The earlier maturing birds of the White Leghorn breed were found in groups 1 and 4 where the smallest egg weights were observed. The latest maturing birds of the same breed belonged to group 6 where the heaviest eggs were found. Groups 2, 3, and 5 were intermediate in maturity and egg size. The correlation coefficient was .413, with 65 degrees of freedom.

The earliest maturing New Hampshires were in groups 1 and 3. The same birds laid the smallest eggs. For the same breed groups 2, 4 and 6, and 5 in table 5 closely correspond to the same groups in table 8. The correlation coefficient was .437, with 96 degrees of freedom.

The earliest maturing Natives and their smallest egg weights belonged to groups 1 and 6. The latest maturing birds were in groups 3, 4, and 5 where the heaviest eggs were found. Group 2, intermediate in maturity, was also intermediate in egg weight. The correlation coefficient was .496, with 37 degrees of freedom.

TABLE NO. 7

EGG WEIGHT OF WHITE LEGHORNS, NEW HAMPSHIRES, AND NATIVES

Breed	Mean Egg Weight (ounces per dozen)					
	1946		1947		Combined Years	
White Leghorn	(67)[1]	20.0	(68)	19.3	(135)	19.6
New Hampshire	(98)	21.1	(165)	20.9	(263)	20.9
Native	(39)	17.9	(33)	16.9	(72)	17.4

	Analysis of Variance		
	d/f	Sums of Squares	Mean Square
Years	1	24.42	24.42**
Breeds	2	750.45	375.22**
Years x Breeds	2	9.86	4.93
Individuals	464	965.87	2.08
			b=1.44

[1] Figures in parenthesis are number of birds.

TABLE NO. 8

EGG WEIGHT BY HATCHES OF WHITE LEGHORNS, NEW HAMPSHIRES, AND NATIVES DURING 1946

Hatch	Mean Egg Weight (ounces per dozen)					
	White Leghorn		New Hampshires		Native	
1	(14)[1]	19.7	(13)	20.3	(5)	16.9
2	(7)	20.2	(16)	21.0	(3)	17.7
3	(14)	20.0	(21)	20.5	(8)	18.1
4	(19)	19.7	(32)	21.5	(13)	18.2
5	(7)	20.3	(6)	22.4	(4)	18.7
6	(6)	21.0	(10)	21.4	(6)	17.2
Average	(67)	20.0	(98)	21.1	(39)	17.9

	Analysis of Variance		
	d/f	Sums of Squares	Mean Square
Breeds	2	314.99	157.49**
Hatches	5	51.25	10.25**
Interaction	10	256.10	.55
Individuals	186	....	1.38
			k=1.18

[1] Figures in parenthesis are number of birds.

TABLE No. 9

EGG WEIGHT BY HATCHES OF WHITE LEGHORNS, NEW HAMPSHIRES, AND NATIVES DURING 1947

Hatch	Mean Egg Weight (ounces per dozen)					
	White Leghorn		New Hampshire		Native	
1	(11)[1]	19.2	(34)	20.6	(10)	16.5
2	(25)	19.2	(39)	20.5	(13)	16.5
3	(32)	19.5	(92)	21.1	(10)	17.7
Average	(68)	19.3	(165)	20.9	(33)	16.9

	Analysis of Variance		
	d/f	Sums of Squares	Mean Square
Breeds	2	426.82	213.41**
Hatches	2	19.42	9.71**
Interaction	4	4.66	1.17
Individuals	257	568.84	2.21
			k=1.49

[1] Figures in parenthesis are number of birds.

The correlation between sexual maturity and egg size can also be observed in the data for 1947 by comparing table 9 with table 6. The earliest maturing birds of all the breeds laid the smallest eggs.

This correlation between maturity and egg weight is probably due to larger body size of the late maturing birds at the time of first egg. Although no data are available to substantiate this statement it seems to be warranted by results obtained by other workers (Jull, 1946).

Body weight

In table 10 the average body weight of the three breeds during 1947 for the first four months of age is presented.

TABLE No. 10

BODY WEIGHT AND THE STANDARD DEVIATION OF WEIGHTS OF WHITE LEGHORNS, NEW HAMSHIRES, AND NATIVES FOR 1947 AT FOUR DIFFERENT AGES

Breed	Age in Months							
	One	S	Two	S	Three	S	Four	S
	(lbs.)		(lbs).		(lbs.)		(lbs.)	
White Leghorns. 68	.56	.09	1.40	.19	2.31	.28	3.02	.33
New Hampshires 165	.57	.06	1.45	.20	2.49	.39	3.21	.43
Natives 33	.45	.07	1.11	.15	1.64	.26	2.16	.27

There were no significant differences in weight between the White Leghorn and the New Hampshire birds at the end of the first and second month of age. However, at the end of the third and fourth month of age the New Hampshires weighed .18 and .19 pounds more, respectively, than the White Leghorns. The t value obtained was 3.31 for the third month and 3.29 for the fourth month. The probability in both cases was less than .01 for 231 degrees of freedom. Both standard breeds were heavier than the Natives at the end of each of the four months. The White Lebhorns weighed .11, .29, .67, and .86 pounds more than the Natives at each of the four months. With 99 degrees of freedom the probability was less than .01 in all cases. The t values obtained were 6.43 for the first month and 7.72, 11.45, and 12.91 for the other three successive months. The New Hampshires weighed .12, .34, .85, and 1.05 pounds more than the Natives at each of the four successive months. With 196 degrees of freedom the probability was also less than .01 in all cases. The t values were 10.50 for the first month and 9.09, 11.91, and 13.39 for the following three successive months.

The variation in weight within the breeds increased constantly from the first to the fourth month of age. The widest variation was found within the New Hampshire at the end of the third and fourth month of age. The Natives varied less than the other breeds at the same ages.

The variation in weight within the breeds increased constantly from the first to the fourth month of age. The widest hatched birds of the White Leghorn and New Hampshire breeds had a tendency to weigh less than those hatched later whereas earlier hatched birds of the Native breed had a tendency to weigh more than those hatched later. The effect of date of hatch on body weight, however, disappeared after the first month of age.

In table 11 the effect of the date of hatch on the body weight of the different breeds at the end of the first month of age is presented. The analysis of variance of these data is also shown in the table.

TABLE No. 11

EFFECT OF DATE OF HATCH ON THE BODY WEIGHT OF WHITE LEGHORNS' NEW HAMPSHIRES, AND NATIVES AT THE END OF THE FIRST MONTH OF AGE

Hatch	Weight in Pounds					
	White Leghorn		New Hampshire		Native	
1	(11)[1]	.52	(34)	.52	(10)	.47
2	(25)	.56	(39)	.57	(13)	.45
3	(32)	.58	(92)	.58	(10)	.43

	Analysis of Variance		
	d/f	Sums of Squares	Mean Square
Breeds	2	.3381	.1690**
Hatches	2	.0850	.0425**
Interaction	4	.0123	.0031
Individuals	257	1.1095	.0043

[1] Figures in parenthesis are number of birds.

Chick mortality

Table 12 shows the chick mortality of the three breeds for 1946 and 1947.

TABLE No. 12

MORTALITY TO ONE MONTH OF AGE OF WHITE LEGHORNS, NEW HAMPSHIRES, AND NATIVES

Year		Breed			
		White Leghorn	New Hampshire	Native	Un-weighted mean
1946	Number hatched	135	145	121	
	No. alive at 1 month	115	122	108	
	Per cent alive	(85.19)	(84.14)	(89.26)	(86.20)
1947	Number hatched	220	616	288	
	No. alive at 1 month	198	567	271	
	Per cent alive	(90.00)	(92.05)	(94.10)	(95.05)
Combined years	Number hatched	355	761	409	
	No. alive at 1 month	313	689	379	
	Per cent alive	(88.17)	(90.54)	(92.67)	(90.46)

The New Hampshire chicks had 7.91 per cent better viability during 1947 than during 1946. A chi-square of 7.68 was obtained, which was highly significant, the probability being

less than .01 for one degree of freedom. However, there were no significant differences between years in respect to the White Leghorn and Native breeds. Also breed differences were not significant in either year.

Laying flock mortality

Table 13 gives the laying flock mortality of the three breeds for 1946 and 1947.

TABLE NO. 13

LAYING FLOCK MORTALITY OF WHITE LEGHORNS, NEW HAMPSHIRES, AND NATIVES

Year		White Leghorn	New Hampshire	Native	Unweighted mean
1946	Number of birds	91	137	58	
	Per cent survivals	21.98	34.31	36.21	30.83
	Per cent with pullorum	48.35	48.17	37.93	44.82
	Per cent dead	29.67	17.52	25.86	21.35
1947	Number of birds	64	219	44	
	Per cent survivals	60.94	78.08	52.27	63.76
	Per cent with pullorum	4.69	0.91	6.82	4.14
	Per cent dead	34.37	21.01	40.91	32.10

The New Hampshire birds had 17.14 per cent better viability than the White Leghorns and 25.81 per cent better viability than the Natives during 1947. A chi-square of 16.04 was obtained, which was highly significant, the probability being less than .01 for two degrees of freedom. There were no significant differences between the White Leghorns and the Natives during the same year.

If birds culled because of pullorum in 1946 are not included among the dead, the laying flock mortality was 23.64 per cent lower in the New Hampshires than in the White Leghorns. With a chi-square of 6.45 this difference was significant, the probability being less than .02 for one degree of freedom. However, there were no significant differences between the New Hampshires or the Leghorns and the Natives. If birds culled because of pullorum in 1946 are included among the dead there were no significant differences between the breeds in mortality during that year.

The New Hampshires had 43.77 per cent better viability in 1947 than in 1946. A chi-square of 66.2 was obtained, with a probability of less than .01 for one degree of freedom.

There were no significant differences in laying flock mortality of the Natives between the years.

Comparison of Crosses

Table 14 summarizes the average egg production, sexual maturity, egg weight, and body weight of the crossbreds and the parental breeds. The data on the chick and laying flock mortality is shown in table 15.

White Leghorn x Native vs. White Leghorn and Native

The White Leghorns laid an average of 12.0 eggs more than the White Leghorns x Natives during the period studied (Table 14). A t value of 3.48 was obtained with 135 degrees of freedom, the probability being less than .01. The White Leghorn x Natives laid an average of 12.5 eggs more than the Natives. With a t value of 3.38 and 100 degrees of freedom the probability was less than .01. The Native birds were more uniform than the other breeds in egg production. The variation within the crossbreds was intermediate between that found in the Leghorns and the Natives. The standard deviation in production was 21.89, 18.43, and 15.42 eggs respectively for the Leghorns, White Leghorn x Natives, and Natives.

There were no significant differences in the sexual maturity of the three breeds (Table 14). However, the variation within the Natives and the crossbreds was much higher than that found within the Leghorns. The standard deviation in sexual maturity was 22.9, 44.84, and 52.07 days for the Leghorns, Crossbreds, and Natives, respectively.

TABLE No. 14

EGG PRODUCTION, SEXUAL MATURITY, EGG WEIGHT, AND BODY WEIGHT OF THE WHITE LEGHORNS, NEW HAMPSHIRES, NATIVES AND CROSSES BETWEEN THEM

Breed	N	Egg production (Mean-120 days)	Age at first egg (days)	Mean egg weight (oz. per dozen)	Body weight (pounds)			
					One month	Two months	Three months	Four month
White Leghorns	68	45.7	192	19.3	0.56	1.40	2.31	3.02
White Leghorns x Natives	69	33.7	202	18.3	0.48	1.20	1.98	2.44
Natives	33	21.2	195	16.9	0.45	1.11	1.64	2.16
New Hampshires x Natives	55	39.9	222	19.0	0.49	1.25	2.13	2.64
New Hampshires	165	47.8	225	20.9	0.57	1.45	2.49	3.21

TABLE NO. 15

CHICK AND LAYING FLOCK MORTALITY OF WHITE LEGHORNS, NEW HAMPSHIRES, NATIVES AND CROSSES BETWEEN THEM

Breed	Chick Mortality			Laying Flock Mortality			
	Number hatched	Number alive at one month	Per Cent alive at one month	N	Survivals	With pullorum	Dead
					Per cent	Per cent	Per cent
White Leghorns	220	198	90.00	64	69.94	4.69	34.37
White Leghorns x Natives	493	471	95.54	122	69.67	4.10	26.23
Natives	288	271	94.10	44	52.27	6.82	40.91
New Hampshires x Natives	665	625	93.98	111	70.27	1.80	27.93
New Hampshires	616	567	92.05	219	78.08	0.91	21.01

The Leghorns laid heavier eggs than the White Leghorn x Natives, with an average of 1 oz. per dozen eggs more (Table 14). A t value of 5.25 was obtained with 135 degrees of freedom, corresponding to a probability of less than .01 that this is a chance difference. The crossbreds laid an average of 1.4 oz. per dozen heavier eggs than the Natives. With a t of 5.16 and 100 degrees of freedom the probability was less than .01. The Natives laid eggs which varied more in size than those laid by the Leghorns and the crossbreds. The standard deviation in egg weight was 1.23, 1.16, and 1.48 oz. per dozen eggs for the Leghorns, White Leghorns x Natives and Natives, respectively.

The weight of the White Leghorn birds were 0.08, 0.20, 0.33, and 0.58 pounds more than that of the crossbreds at the end of the first, second, third, and fourth month of age, respectively (Table 14). For 135 degrees of freedom the probability was less than .01 in all cases that these are chance differences. The t values obtained were 5.79, 6.67, 6.56, and 11.12, respectively, for each of the four months. The weights of the crossbreds were similar to the Natives for the first month of age but they were .09, .34, and .28 pounds heavier at the second, third, and fourth months, respectively. For 100 degrees of freedom the probability was less than .01. The t values for testing significance were 2.72, 5.38, and 4.93 for the second, third, and fourth months, respectively. The variation in weight within the crossbreds was more or less intermediate between that found in the Leghorns and the Natives in all months except the third. The standard deviations of their weights during each of the four months were .08, .16, .31, and .27 pounds as compared with .09, .19, .28, and .33 pounds for the Leghorns and .07, .15, .26, and .27 pounds for the Natives.

The White Leghorns x Natives had 5.54 per cent better chick viability than the White Leghorns (Table 15). A chi-square of 8.27 was obtained, which has a probability of less than .01 for one degree of freedom. There were no significant differences between the crossbreds and the Natives in chick mortality.

The White Leghorn x Native laying hens had 17.40 per cent better viability than the Natives (Table 15). With one degree of freedom, a chi-square of 4.49 was significant for a probability less than .05. There were no significant differences between the crossbreds and the Leghorns in laying flock mortality.

New Hampshire x Native vs. New Hampshire and Native

The New Hampshires laid an average of 7.9 eggs more than the New Hampshire x Natives during the period studied (Table 14). A t value of 2.66 was obtained which was highly significant ($P > .01$) for 218 degrees of freedom. The crossbreds laid an average of 18.7 eggs more than the Natives. A t value of 5.45 obtained with 86 degrees of freedom had a probability of less than .01. The variation within the crossbreds and the Natives was less than that found in the New Hampshires. The standard deviation in production was 19.99, 15.69, and 15.42 eggs for the New Hampshires, New Hampshires x Natives, and Natives, respectively.

The Natives were 27 days earlier in maturity than the crossbreds (Table 14). The t value calculated was 2.43, which for 86 degrees of freedom has a probability of less than .05. There were no significant differences between the crossbreds and the New Hampshires. The Natives and the New Hampshire x Natives varied more in maturity than the New Hampshires. The standard deviation in sexual maturity were 41.32, 49.59, and 52.07 days for the New Hampshires, crossbreds and Natives, respectively.

The New Hampshires laid eggs weighing 1.9 oz. per dozen more than those laid by the crossbreds (Table 14). A t value of 7.29 was obtained, the probability being less than 0.1 for 218 degrees of freedom. The New Hampshires x Natives laid eggs averaging 2.1 oz. per dozen heavier than the Natives. With a t value of 6.35 and 86 degrees of freedom the probability was less than .01. The variation in egg weight was more marked within the New Hampshires and the crossbreds than within the Natives. The standard deviations in egg weight

were 1.60, 1.59, and 1.48 oz. per dozen eggs for the New Hampshires, New Hampshire x Natives and the Natives, respectively.

The weight of the New Hampshire birds was .08, .20, .36, and .57 pounds more than that of the crossbreds at the end of the first, second, third and fourth month of age, respectively (Table 14). For 218 degrees of freedom the probability was less than .01 in all cases; the t values obtained being 7.41, 6.34, 6.11, and 8.14 for each of the four months. The crossbreds were .04, .14, .49, and .48 pounds heavier than the Natives at the end of the first, second, third and fourth month of age, respectively. For 86 degrees of freedom the probability was less than .05 at the first month and less than .01 at the second, third and fourth month. The corresponding t values were 2.32, 3.56, 7.99, and 5.24 for each month. The standard deviations in body weight of the crossbreds during each of the four months were .09, .19, .29, and .49 pounds as compared with .06, .20, .39, and .43 pounds for the New Hampshires and with .07, .15, .26, and .27 pounds for the Natives.

There were no significant differences between the breeds in chick mortality (Table 15).

The New Hampshire x Natives had 18 per cent better laying flock viability than the Natives (Table 15). A chi-square of 4.31 was obtained, which was significant at the .05 level of probability. There were no significant differences between the crossbreds and the New Hampshires in laying flock mortality.

New Hampshire x Native vs. White Leghorn x Native

There were no significant differences in egg production between the crossbreds although the New Hampshires x Natives had a tendency to lay better (Table 14).

The White Leghorn x Natives were 20 days earlier in maturity than the New Hampshires x Natives (Table 14). The t value obtained was 2.31 and the probability was less than .05 for 122 degrees of freedom.

The New Hampshires x Natives laid eggs weighing 0.7 oz. per dozen more than those laid by the White Leghorn x Natives (Table 14). With a t value of 3.15 the probability was less than .01 for 122 degrees of freedom.

The weight of the New Hampshire x Native birds was .01, .05, .15, and .20 pounds more than that of the White Leghorn x Natives (Table 14). The differences were not significant during the first two months. At the third and fourth months of

age the New Hampshire x Natives were significantly heavier than the White Leghorns x Natives. A t value of 2.86 for the third month and of 2.92 for the fourth month was obtained; the probability was less than .01 for 122 degrees of freedom.

The growth curves of the crossbreds and purebreds are presented in Figure 1.

The crossbreds were more or less alike in chick mortality and laying flock mortality. However, both crossbreds, with a percentage chick viability of 94.65, were significantly superior to the purebreds (White Leghorn, New Hampshire, Native) with a percentage chick viability of 92.17. A chi-square of 5.69 was obtained with a probability of less than .02 for one degree of freedom.

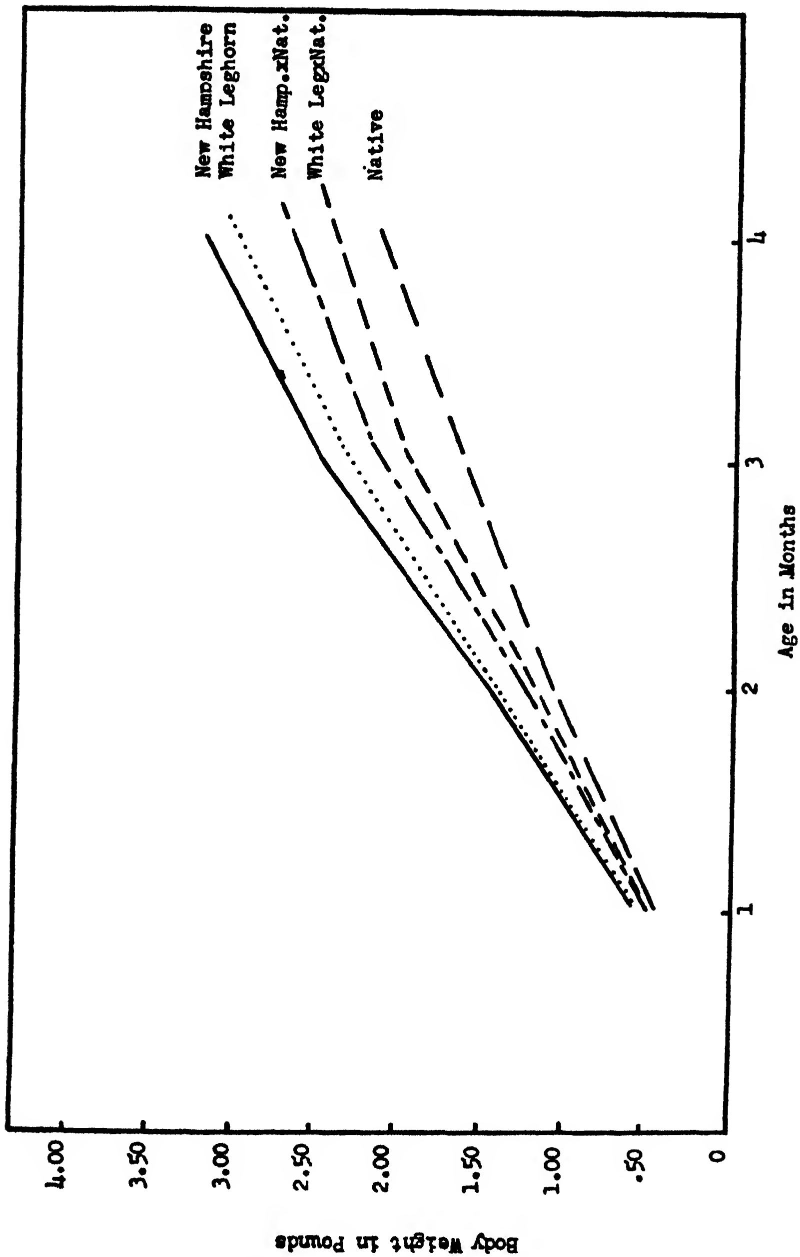

FIG. 1.—Comparative growth to four months of purebred and crossbred chickens.

Discussion

Practical and important differences were found between the Native Puerto Rican fowl and the standard breeds in respect to their productive capacity. As regards egg production, egg weight, and body weight the native fowl would appear to contribute very little, if anything, to the attainment of a more productive breed for Puerto Rico. The differences between the Native and the standard breeds in those characters, viz. 21.2 eggs in production during the first 120 days of laying, 3.5 oz. per dozen in egg weight, and 1.05 lbs. in body weight at the end of the fourth month of age, are quite conclusive and indicative of the advisability of substituting for the Native breed a more productive breed as a first step for increasing poultry production in the Island.

The superiority of the standard breeds in respect to sexual maturity was not so evident but the study of this character is only useful as a help in evaluating egg production. Laying flock mortality was heavy for all the breeds but the New Hampshires fared better than the Natives. However, the conditions of this experiment were such as to enable the native fowls to fully express their potentiality in respect to body weight, egg production and egg weight but it is questionable if they were adequate to enable them to fully express their potentiality in the qualities of viability and resistance to disease. The natural habitat of the native fowl in the Island is very different from that used in this experiment where, although *S. pullorum* was present in the flock, the birds were protected as far as possible against adverse conditions and against disease and parasites.

Some improvement through adequate selection within the Native breed is considered possible, but on the basis of the results shown the use of other possibilities available for the development of a better breed for Puerto Rico seems more practical and economical.

Assuming that selection would be exclusively for egg production and that the effectiveness of the selection practiced were 100 per cent; that the females and males kept for replacement purposes were 20 and 2 per cent, respectively, of the population available; that the standard deviation in production would remain more or less constant around 15 eggs, which was the figure obtained in 1947; and that the heritability of egg pro-

duction is of the order of 10 per cent; the time required to raise the egg production of the Natives from an average of 21.2 eggs during the first 120 days of laying to the average of the New Hampshire, 47.8 eggs would be around 9 generations or approximately 14 years (Lush, 1945). Actually, much more than 14 years would be necessary to raise the egg production of the Natives to a level comparable with that of the New Hampshires because the selection could not be done for egg production alone and its effectiveness would be much less than 100 per cent. Also the replacement percentage probably would be higher due to the high mortality rates in the flocks of the Island.

The crosses represent a distinct improvement over the Natives in respect to the productive characters but they are inferior to the standard breeds in egg production, egg weight, and body weight. Their production and egg weight was intermediate between that of the Natives and the standard breeds. Body weight was slightly nearer the smaller sized breed. Similar results were obtained with other breeds by Jull and Quinn and by Maw, cited by Jull (1946). In respect to sexual maturity, the White Leghorn cross was similar to the White Leghorn while the New Hampshire cross was similar to the New Hampshire.

There is some indication in the data that the crosses may perform better than the standard breeds in respect to resistance and viability although that is not so apparent when comparing them with the New Hampshire. The ultimate value of the crosses as a possibility for developing a better breed for Puerto Rico will depend upon the existence of actual resistance or adaptability in the Native stock, that is, in the contribution, if any, that the Native can give to a new breed.[1]

The possibility of developing some strain from one of the standard breeds which will make it more desirable than the Native for Puerto Rican conditions is apparent from this study. The New Hampshire breed was superior to the White Leghorn in egg weight, body weight, and mortality. They were similar in egg production and the New Hampshire was inferior only in sexual maturity. Except in chick mortality and sexual maturity the New Hampshire stock surpassed the Native breed in all characters. So far as the characters studied are concerned

[1] The breeding work is being continued at the Station with several backcross lines.

the New Hampshire seems to offer a distinct possibility for developing a strain which would be more desirable than the Native for Puerto Rico.

However, in some of the characters, especially in egg production and egg weight, the standard breeds in this study were inferior to selected flocks in the United States. This lower production and smaller egg size may have been due to a physiological response of the birds in their adaptation to a tropical environment. Results obtained by Warren (1933, 1939) tend to indicate that the smaller egg size could be due to environmental effects. This possibility, however, should be further investigated.

Seasonal effects were found to be important in this study in respect to egg production, sexual maturity, egg weight, and body weight at the end of the first month of age. Differential responses of the birds of the different breeds to these seasonal effects were apparent in respect to sexual maturity and body weight at the end of the first month of age. This environmental influence was more evident from February to June than from February to March.

CONCLUSIONS

Much more information would be necessary before a definite conclusion on the main objectives of this study could be advanced. However, it is considered that sufficient evidence has been collected to justify drawing the following conclusions:

1. The productive capacity of the Native fowl, as judged by egg production, egg weight, and body weight, is inferior to that of the standard breeds studied.
2. Selection within the Native would be a long and non-economical proposition as a means of getting a better breed of poultry for the Island.
3. Crosses between the Native and the standard breeds will show some improvement over the pure Natives but will be inferior to the standard breeds in their productive capacity.
4. There is no definite or immediately apparent superiority of the Natives in respect to viability and resistance over the imported breeds under the conditions in which this experiment was made.

Due to the peculiarities of the poultry management and care in the small farms of the Island it would be desirable to study

the same characters considered here under those conditions. The study should be extended to include fertility, hatchability, mortality during the growing period, efficiency of food utilization, resistance to parasites (which constitutes an important problem in the Island), and physiological responses of the different breeds to the environment. Studies of this nature should be undertaken under experimental and farm conditions.

Allowance for the date of hatching, as a factor influencing some of the characteristics studied here, should be made when planning further comparisons between breeds. The advisability of including other strains of White Leghorns and New Hampshires for comparison and crossing purposes should also be considered in future plans.

It is felt that the ideal fowl for Puerto Rico would possibly be a medium size bird, with high efficiency of food utilization, laying relatively well, with some broodiness and good adaptability to the environment. Such a bird, replacing the Native stock, would increase poultry meat and egg production in the Island with minimum expense on the part of the farmer.

Summary

The productive capacity of the Native Puerto Rican fowl was compared with White Leghorns and New Hampshires reared under similar conditions. Data were recorded on egg production, sexual maturity, egg weight, body weight to four months of age, and mortality. Studies of an exploratory nature were made of the possibilities of crosses between the Native and the standard breeds.

It was found that the productive capacity of the Native fowl, as judged by egg production, egg weight and body weight, was inferior to that of the White Leghorn and New Hampshire. The Native crosses showed improvement over the pure Natives, but were inferior to the standard breeds although there was some indication that they may possess a greater amount of disease resistance.

Under the conditions of the experiment there was no apparent superiority of the pure Natives over the imported breeds in respect to viability and resistance.

Extension of the study to cover the physiological responses of the different breeds to the environment under experimental and farm conditions is recommended.

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EFFECT OF LIME-PHOSPHORUS AND GREEN MANURE ON SWEET POTATOES AND CORN GROWN IN ACID SOILS

By J. A. BONNET, P. TIRADO SULSONA and F. ABRUÑA [1]

INTRODUCTION

In general, the yields of food crops that grow in the acid soils of the humid area of Puerto Rico, have been low because no attention has been given to the correction of soil deficiencies. It was of importance, therefore, to obtain data of their yields when lime, phosphorus and green manure were added to these acid soils.

The effect of lime and phosphorus added to two acid soils in Puerto Rico was studied on the yields of seven crops in a rotation sequence of green manure, green manure, sweet potatoes, green manure, green manure, corn and corn, in a three-year period from May 1944 to August 1947 at two locations, Río Piedras and Mayagüez.

Each crop of green manure included four leguminosae; velvet beans *Stizolobium deeringianum*, crotalaria *Crotalaria striata*, cowpeas *Vigna sinensis*, and soybeans *Soja max*, Otootan variety. Data for the first two crops of the four leguminosae have been reported by Bonnet et al. (1). The combined experiments at Río Piedras and Mayagüez, excluding the crotalaria because of its poor growth in Mayagüez, had indicated that:

"1. The mean dry-matter yield of velvet beans in the presence or absence of the lime and phosphorus application or as a whole, was significantly higher at the 1 per cent point, than that of cowpeas and soybeans; whereas that of cowpeas was higher than that of soybeans.

"2. The mean dry-matter yield of velvet beans with lime and phosphorus, was significantly higher at the 1 per cent point, than that of velvet beans without lime and phosphorus. The same applies to soybeans, and cowpeas."

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[1] Respectively, Head Dept. of Soils, and two Jr. Soil Conservationists. This work was undertaken in cooperation with the Soil Conservation Service of Puerto Rico, of which Mr. E. A. Telford, Assoc. Soil Conservationist was in charge of the field experiments at Mayagüez, and with the Federal Experiment Station that provided land and office space at Mayagüez.

The combined experiments at Río Piedras, including the crotalaria had indicated that:

"1. The mean dry-matter yield of velvet beans in the presence or absence of lime and phosphorus applications or as a whole, was significantly higher at the 1 per cent point, than that of cowpeas, soybeans and crotalaria; whereas that of cowpeas was higher than that of soybeans, and crotalaria. The soybeans yield was significantly higher at the 5 per cent point, than that of the crotalaria, in the absence of lime and phosphorus, and significantly lower in their presence; but as a whole there was no significant mean difference between them.

"2. The velvet beans, soybeans and crotalaria, responded significantly at the 1 per cent point, to the application of lime and phosphorus. The cowpeas showed no response to the fertilizer.

"3. Velvet beans, the highest yielder, gave for both locations, in the absence or presence of lime and phosphorus, mean green matter of 83.5 and 110.0 hundredweights per acre, respectively. This is equivalent to mean dry-matter of 17.4 and 22.6 hundredweights per acre."

Results obtained with the other five crops in the rotation, sweet potatoes, green manure, green manure, corn and corn are reported in this paper.

Procedure

Location.—The two locations where the experimental fields were established are within the humid section; Río Piedras at the North of Puerto Rico on 18°–24′N. latitude and 63°–03′W. longitude and Mayagüez at the West on 18°–12′N. latitude and 67°–09′W. longitude. The linear distance between both locations is 120 kilometers or 74.5 miles.

Soils.—Two one-acre fields of the soil type Fajardo clay, at the Experiment Station farm in Río Piedras, and two of Catalina clay level phase, at Las Ochenta farm in Mayagüez, were chosen for the sites of the experiment. Two fields were chosen at each place to study also the effect of two methods of incorporating green manure on the crop yield of sweet potatoes and corn. In field "A" the green manure was turned-under with a hoe, as done by small farmers and in field "B" it was plowed under with a tractor-driven plow, as done by the large landowners. Fajardo clay is a red soil derived from ashy shales.

Catalina clay level phase is a lateritic soil derived from andesitic tuff and tuffaceous shale. The total base exchange capacity of Fajardo clay is between 14 and 22 mili-equivalents per 100 grams of soil and that of Catalina clay between 8 and 14.

Crop Rotation and Treatment.—The crop rotation sequence, the dates of planting, and the mean age at harvest, for each crop, are reported in table 1.

TABLE No. I

ROTATION SEQUENCE, PLANTING DATES AND AGE OF CROPS AT RIO PIEDRAS AND MAYAGUEZ

Rotation Sequence	Crop	Location	Date of Planting	Mean Age at Harvest
			1945	DAYS
THIRD	Sweet potatoes	Río Piedras	Feb. 1 5	142
		Mayagüez	April 1-7	168
FOURTH	Velvet beans	Río Piedras	Oct. 8-10	86
	Crotalaria		Oct. 8-10	86
	Cowpeas		Oct. 8-10	57
	Soybeans		Oct. 8-10	57
	Velvet Beans	Mayagüez	Oct. 8-17	84
	Crotalaria		Oct. 8-17	77
	Cowpeas		Oct. 8-17	59
	Soybeans		Oct. 8-17	59
			1946	
FIFTH	Velvet beans	Río Piedras	April 24-26	82
	Crotalaria		April 24-26	82
	Cowpeas		April 24-26	60
	Soybeans		April 24-26	60
	Velvet beans	Mayagüez	Feb. 24—March 5	103
	Crotalaria		Feb. 24—March 5	87
	Cowpeas		Feb. 24—March 5	66
	Soybeans		Feb. 24—March 5	66
SIXTH	Corn	Río Piedras	Sept. 5-8	102
		Mayagüez	August 8-10	91
			1947	
SEVENTH	Corn	Río Piedras	April 28	100
		Mayagüez	May 15-20	94

Sweet potato (*Ipomea Batatas* Don Juan variety) cuttings, about 12 to 14 inches long, were planted at the rate of two per hole, with an 18-inch separation between holes and with a three-foot distance between rows. The potatoes were dug out and the trash was left over each respective plot.

The leguminosae were planted at a one-foot distance between rows. The distance between plants for the velvet beans was six

inches and for the cowpeas and soybeans was four inches. The crotalaria seeds were planted continuously within the row.

The corn (*Zea Mays* Mayorbela variety) was planted at a three-foot distance between rows and at eighteen inches between plants within the row. Four corn seeds were placed in each hole and after germination two plants were left at each hole. The crop was sprayed with lead arsenate, at the rate of three-pounds per 100 gallons of water, for the control of the leaf worm *Laphygma frugiperda.* Rats were kept under control using a bait of phosphorus paste with corn flour or with pieces of ripe bananas. The corn trash was left over each respective plot.

Half of the plots in each field received limestone at the rate of four tons per acre and superphosphate at the rate of 100 pounds P_2O_5 per acre. The limestone was broadcast and the phosphorus was applied in the row. For the second corn crop, (the seventh crop) half of the plots in each field received a second application of superphosphate at the rate of 100 pounds P_2O_5 per acre as well as muriate of potash at the rate of 240 pounds K_2O per acre. Half of the checks of this corn crop received ammonium sulphate at the rate of 250 pounds NH_3 per acre.

After the first corn crop (the sixth in the rotation) was harvested, soil samples were taken at a depth of four inches from each plot in each of the two fields at both locations and were analyzed for pH, organic matter, nitrates and available phosphorus. Total nitrogen was determined in the composite samples for each treatment at each field in both locations. The data are reported in table 8.

The organic matter was determined by the rapid colorimetric method using the Cenco Wildë organic matter color scale No. 28303, sold and explained by Central Scientific Co., Chicago. The nitrates and available phosphorus were determined, as per Wolfe's (2), extracting with Morgan's solution of normal sodium acetate, buffered at pH 4.8, with acetic acid.

Experimental Data

The yields at Río Piedras and Mayagüez, for the crop sequence sweet potatoes, green manure, green manure, corn and corn, are reported in tables 2, 4 and 5, respectively. The columns "mulched and hoed" correspond to fields "A" and those

for "turned under" correspond to fields "B". The symbols Ca, P, N and K refer to calcium, phosphorus, nitrogen and potassium, respectively.

Statistical Interpretation

The Sweet Potato Crop.—The acre yields in hundredweights of sweet potatoes with the different green manure and fertilizer treatments, are given in table 2. Data are reported separately for the crops grown at Río Piedras and Mayagüez and for each field where the green manure was either mulched and hoed or plowed under the soil.

The analysis of the total sum of squared deviations for the combined crops of sweet potatoes harvested at Río Piedras and Mayagüez is given in table 3.

There is a highly significant difference in the mean yields of sweet potatoes between locations. The acre mean yield of sweet potatoes in the untreated plots at Río Piedras was 98.4 hundredweights and in Mayagüez was 40.8. The mean acre yield of sweet potatoes in the plots that received lime and phosphorus at Río Piedras was 122.8 hundredweights and in Mayagüez was 63.2. In both locations, the increases in yields of sweet potatoes, due to lime and phosphorus, were highly significant (tables 2, 3).

TABLE No. II

YIELDS IN HUNDREDWEIGHTS OF SWEET POTATOES TO THE ACRE, WITH THE DIFFERENT GREEN MANURE AND FERTILIZER TREATMENTS

Treatments	Río Piedras		Mayaguez		Treatments	General
	Mulched and Hoed	Plowed Under	Mulched and Hoed	Plowed Under		
Check	103.6	109.7	47.1	38.1	74.6	
Check with Ca.P.	124.4	129.7	56.9	61.5	93.1	83.9
Velvet beans	119.9	116.8	44.4	58.7	85.1	
Velvet with Ca.P.	136.0	146.6	71.3	87.1	110.3	97.7
Crotalaria	126.7	110.2	49.5	38.9	81.3	
Crotalaria with Ca.P.	129.7	128.0	55.1	60.7	93.4	87.4
Cowpeas	74.3	55.6	37.6	28.9	49.1	
Cowpeas with Ca.P.	101.0	91.4	61.4	58.5	78.8	64.0
Soybeans	89.2	78.3	25.4	39.7	58.2	
Soybeans with Ca.P.	120.2	121.2	57.5	58.8	89.4	73.8
Values to be exceeded for significance by difference between means of:						
At 5% point					12.5	8.8
At 1% point					16.4	11.6

The yields of sweet potatoes planted in the velvet beans plots were significantly higher than in the cowpeas, soybeans and

check plots. The cowpeas showed a highly significant detrimental effect in the yield of sweet potatoes; the cowpeas plots gave 64.0 hundredweights to the acre while the checks gave 83.9 (table 2).

There was no significant difference in the yields of sweet potatoes between the fields (table 3) at both locations when the green manure was either mulched and hoed or plowed under the soil. However, there was a highly significant difference between location, species, and lime-phosphorus treatment. There was also a highly significant interaction of species x lime-phosphorus, of species x location; of species x fields and of lime-phosphorus x fields.

TABLE No. III

ANALYSES OF THE TOTAL SUM OF SQUARED DEVIATIONS FOR THE CROPS OF SWEET POTATOES AT RIO PIEDRAS AND MAYAGUEZ

Source	Degrees of Freedom	Sum of Squares	Variance	F—Values	
Location	1	408, 716	408, 716	537. 1**	
Fields	1	50	50	. 1	
Location x Fields........Error (a)	1	761	761	....	
Species	4	47, 779	11, 945	45. 9**	16. 5*
Lime—Phosphorus	1	48, 927	48, 927	188. 2**	67. 8*
Species x Lime—Phosphorus	4	4, 766	1, 192	4. 6**	1. 7
Species x Location	4	16, 613	4, 153	16. 0**	
Lime—Phosphorus x Location	1	83	83	. 3	
Species x Lime—Phosphorus x Location	4	773	193	. 7	
Species x Fields	4	4, 235	1, 059	4. 1**	
Lime—Phosphorus x Fields	1	1, 123	1, 123	4. 3*	
Species x Lime—Phosphorus x Fields	4	632	158	. 6	
Species x Location x Fields	(4)	(1, 191)	(298)	1. 2	
Lime—Phosphorus x Location x Fields	(1)	(191)	(191)	. 7	
Species x Lime—Phosphorus x Location x Fields	(4)	(954)	(239)	. 9	
Error (b)	9	2, 336	260	....	
Blocks	32	153, 963	....	....	
Treatments x Blocks.....Error (c)	288	207, 949	722	....	

Error (b)—For conclusions applicable to varying soil and climatic conditions in Puerto Rico.
Error (c)—For comparisons with a location. Used in last F—Column.

The Legume Crops.—The green manure and the dry yields of the fourth and fifth crops including velvet beans, crotalaria, cowpeas and soybeans, with or without lime and phosphorus at Río Piedras and Mayagüez, are reported in table 4.

The four leguminosae responded in a highly significant way to the application of lime and phosphorus. Among them, velvet beans gave the highest yield. Similar results were obtained previously by Bonnet et al (1). The mean green weight for the two crops of velvet beans, at both fields in Río Piedras and Mayagüez, was 74.7 hundredweights to the acre for the un-

treated plots and 100.5 for the plots that received lime and phosphorus. On the basis of dry weight the respective values were 17.7 and 24.4 hundredweights.

TABLE No. IV

ACRE YIELDS IN HUNDREDWEIGHTS OF THE FOURTH AND FIFTH CROPS, THE TWO CONSECUTIVE LEGUMINOSAE CROPS WITH THE DIFFERENT FERTILIZER TREATMENTS

Treatments	Río Piedras				Mayagüez			
	Mulched and Hoed		Plowed Under		Mulched and Hoed		Plowed Under	
	Fourth Crop	Fifth Crop	Fourth Crop	Fifth Crop	Fourth Crop	Fifth Crop	Fourth Crop	Fifth Crop
	Green Weight				Green Weight			
	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.
Velvet beans	49.1	124.3	27.7	160.6	76.7	79.0	26.6	53.6
Velvet beans with Ca P	67.1	180.4	40.2	174.8	71.7	125.8	42.2	101.8
Crotalaria	29.2	42.0	20.2	33.2	21.4	26.7	17.0	18.1
Crotalaria with Ca P	35.0	58.7	24.8	53.0	34.3	40.9	19.2	33.6
Cowpeas	32.7	66.0	35.7	56.7	11.5	18.9	21.0	10.8
Cowpeas with Ca P	53.8	113.4	55.7	98.4	11.5	21.1	21.6	42.3
Soybeans	10.6	33.1	18.3	37.1	18.3	11.9	11.8	2.6
Soybeans with Ca P	16.9	65.7	30.0	87.4	31.6	18.6	22.0	3.2

Treatments	Río Piedras				Mayagüez			
	Mulched and Hoed		Plowed Under		Mulched and Hoed		Plowed Under	
	Fourth Crop	Fifth Crop	Fourth Crop	Fifth Crop	Fourth Crop	Fifth Crop	Fourth Crop	Fifth Crop
	Dry Weight				Dry Weight			
	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.
Velvet beans	14.2	28.2	8.0	37.6	22.8	15.7	7.8	14.1
Velvet beans with Ca P	18.0	41.7	11.5	42.4	20.3	24.9	11.5	25.0
Crotalaria	6.8	9.8	5.0	8.2	7.2	6.0	5.7	5.1
Crotalaria with Ca P	7.7	14.4	6.1	13.2	11.4	7.1	6.5	9.2
Cowpeas	4.6	9.6	4.9	7.5	3.3	4.1	3.9	2.5
Cowpeas with Ca P	7.7	16.6	7.8	14.1	3.0	4.6	4.5	3.3
Soybeans	2.6	10.7	4.4	8.1	5.4	4.3	3.4	1.1
Soybeans with Ca P	4.0	15.1	7.2	19.4	9.5	6.7	6.2	1.3

The Corn Crops.—The shelled corn yields in hundredweights to the acre, of the sixth crop in the rotation with the different green manure and fertilizer treatments at both fields, in Río Piedras and Mayagüez are given in table 5. The data were analyzed for each field and for both fields at each location.

There was a highly significant response of corn yields to the applications of lime and phosphorus (table 5, photos 1, 2, 5). The yields at Río Piedras were higher. At both locations the green manure from velvet beans that received lime and phos-

phorus gave the highest significant increases in corn yields over those of the corresponding checks (photos 2, 3, 4, 5). In general, the corn yields obtained in the velvet beans plots were the highest. The mean acre yield of shelled corn for the velvet beans treatment in both fields at Río Piedras were 24.6 and 17.1 hundredweights, with and without lime and phosphorus, respectively. These yields correspond to 41 and 28.5 bushels

TABLE No. V

ACRE YIELDS OF SHELLED CORN IN HUNDREDWEIGHTS FOR THE SIXTH CROP WITH THE DIFFERENT GREEN MANURE AND FERTILIZER TREATMENTS

Treatments	Río Piedras		Mayagüez	
	Mulched and Hoed	Plowed Under	Mulched and Hoed	Plowed Under
Check	11.7	10.5	1.6	1.7
Check with Ca P.	17.0	19.2	6.1	9.7
Velvet beans	15.3	18.9	6.2	4.3
Velvet beans with Ca P	24.7	24.4	13.3	17.9
Crotalaria	14.7	13.4	2.3	3.1
Crotalaria with Ca P	20.8	19.1	8.1	11.5
Soybeans	10.6	10.7	3.4	3.4
Soybeans with Ca P	22.0	21.8	8.2	10.2
Cowpeas	15.9	9.8	2.5	1.7
Cowpeas with Ca P	24.4	20.6	7.7	10.7
Values to be exceeded for significance by difference between treatments:				
At 5% point	5.7	4.7	4.8	3.6
At 1% point	7.5	6.3	3.6	4.8

of corn, respectively. At Mayagüez, the green manure from velvet beans that received lime and phosphorus gave the highest significant increases in corn yields over those of the other three sources, but at Río Piedras, there was no significant difference between them.

The acre yields of shelled corn, in hundredweights, for the seventh and last crop in the rotation, with the different green manure and fertilizer treatments at both fields in Río Piedras and Mayagüez, are reported in table 6. The analysis for the total sum of squared deviations for this crop at both locations is reported in table 7.

TABLE No. VI

ACRE YIELDS OF SHELLED CORN IN HUNDREDWEIGHTS FOR THE SEVENTH CROP WITH THE DIFFERENT GREEN MANURE & FERTILIZER TREATMENTS

Treatments	Río Piedras		Mayagüez		Treatments	Genera
	Mulched and Hoed	Plowed Under	Mulched and Hoed	Plowed Under		
Nitrogen	11.3	6.6	6.0	1.2	6.2 (8)*	
Nitrogen with K	4.5	6.1	21.0	5.4	8.8 (10)	
Nitrogen with CaP	16.9	14.9	15.9	6.3	13.5 (8)	
Nitrogen with CaPK	12.8	15.5	35.6	25.1	22.3 (10)	12.7
Velvet beans	6.3	10.2	11.6	4.0	7.9 (8)	
Velvet beans with K	6.1	4.7	9.4	1.8	5.4 (10)	
Velvet beans with CaP	12.1	8.2	21.9	8.8	12.4 (8)	
Velvet beans with CaPK	15.7	13.1	20.3	16.0	15.6 (10)	10.3
Crotalaria	8.0	9.2	9.7	3.8	7.5 (8)	
Crotalaria with K	4.9	4.1	8.4	2.7	4.9 (10)	
Crotalaria with CaP	11.7	14.2	23.9	8.9	14.3 (8)	
Crotalaria with CaPK	15.5	9.8	13.4	13.8	12.6 (10)	9.8
Cowpeas	7.4	4.1	6.6	4.7	5.5 (8)	
Cowpeas with K	9.1	5.9	11.0	2.5	7.0 (10)	
Cowpeas with CaP	16.3	11.8	13.5	11.4	12.8 (8)	
Cowpeas with CaPK	13.0	14.0	19.9	12.3	14.3 (10)	9.9
Soybeans	2.5	7.4	9.8	3.2	5.6 (8)	
Soybeans with K	6.3	3.6	8.4	1.2	4.8 (10)	
Soybeans with CaP	11.3	15.3	18.6	9.5	13.3 (8)	
Soybeans with CaPK	13.1	12.0	20.2	18.1	15.1 (10)	9.7
Values to be exceeded for significance by difference between means of:						
At 5% point					4.32 (16) 4.08 (18) 3.87 (20)	1.99(72)
At 1% point					5.70 (16) 5.38 (18) 5.10 (20)	2.69(72)

* Number of replicates.

TABLE No. VII

ANALYSES OF THE TOTAL SUM OF SQUARE DEVIATIONS FOR THE LAST CORN CROPS AT RIO PIEDRAS AND MAYAGUEZ

Source	Degrees of Freedom	Sum of Squares	Variance	F—Values	
TOTAL	359	22,552			
Fields	1	1,333	1,333	1.6	
Location	1	421	421	.5	
Fields x Location ...... Error (a)	1	828	828		
Treatments	(19)	(9,140)	(481)	2.0	79.6**
Species	4	635	159	.6	26.3**
Lime—Phosphorus	1	7,076	7,076	28.7**	1,171.6**
Potassium	1	154	154	.6	25.5**
Lime—Phosphorus—Potassium	1	257	257	1.0	42.6**
Species x Lime—Phosphorus	4	205	51	.2	8.5**
Species x Potassium	4	646	161	.7	26.7**
Species x Lime—Phosphorus x Potassium	4	167	42	.2	6.9**
Treatments x Fields	19	354	19	.1	
Treatments x Locations	19	4,099	216	.9	
Treatments x Locations x Fields. Error (b)	19	4,687	247		
Error (c)	280	1,691	6		

Error (b)—For conclusions applicable to varying soil and climatic conditions in Puerto Rico.
Error (c)—For comparisons within a location. Used in last F—Column.

There was again a highly significant difference in corn yields for the lime-phosphorus treatment (table 7) as found before for sweet potatoes (table 3). The difference between fields again was not significant indicating once more that there was no significant difference in corn yields when the green manure was either mulched or plowed under. This time there was no signicant difference in the crop yield due to species when applied to general conditions in Puerto Rico, but this difference was highly significant for comparisons within a location (table 7). For general conditions in Puerto Rico there was no significant difference in corn yields due to the addition of potassium or to the interactions of lime-phosphorus x potassium and of species x potassium but the difference was highly significant for comparisons within a location. For example, the addition of potassium alone to the mulched and hoed field at Mayagüez when inorganic nitrogen was added, at the rate of 250 pounds NH_3 to the acre, raised the acre yield of shelled corn from 6.0 to 21 hundredweights and to 35.6 when lime-phosphorus was added. In the field at Mayagüez, where the corresponding green manures were plowed under, there was a significant increase in yield of 25.1 hundredweights of shelled corn, to the acre, only, when the potassium was added with lime and phosphorus. The yield responses indicate that the fields of Catalina clay at Mayagüez were deficient in potash, while those at Río Piedras, of Fajardo clay, had sufficient of this element.

Twenty seven months after the lime and phosphorus were applied (table 8), the mean pH of the soil for the five treatments including the check, at both fields in Mayagüez was 5.5, while that in Río Piedras was 5.0. The mean pH for the acid plots was 4.7 at Mayagüez and 4.8 at Río Piedras. The mean organic matter content for all treatments in both fields at Mayagüez was 2.2 per cent and at Río Piedras was 1.6. The mean nitrogen content at Mayagüez was .19 per cent and at Río Piedras was .16. The mean carbon-nitrogen ratios were 6.8 and 5.8, respectively. In the lime-phosphorus plots the mean available phosphorus for the five treatments including the check, at Mayagüez, was 13 parts per million of phosphorus (P), and at Río Piedras was 10. For the acid plots the values were 8 and 9, respectively. The mean values for nitrates in the lime-phosphorus plots at Mayagüez was 9 parts per million and at Río Piedras was 14 while for the acid plots were 14 and 10, respectively.

TABLE NO. VIII

CHEMICAL DATA OF SOIL SAMPLES TAKEN TWENTY SEVEN MONTHS AFTER THE LIME AND PHOSPHORUS WERE APPLIED WHEN THE FIRST CORN CROP WAS HARVESTED

Treatments	Río Piedras						Río Piedras					
	Mulched and Hoed						Plowed Under					
	pH	N	Org. Matter	C/N	NO_3	P	pH	N	Org. Matter	C/N	NO_3	P
		%	%		p.p.m.	p.p.m.		%	%		p.p.m.	p.p.m.
Check	4.8	.17	1.7	5.8	14	10	4.7	.15	1.4	5.4	13	9
Check with Ca P	5.0	.17	1.8	6.1	14	10	5.0	.16	1.4	5.1	12	9
Velvet beans	4.9	.17	1.6	5.5	16	9	5.0	.16	1.5	5.4	17	9
Velvet beans with Ca P	5.3	.17	1.8	6.1	13	13	5.0	.15	1.5	5.8	16	9
Crotalaria	4.9	.16	1.7	6.2	17	9	4.7	.14	1.5	6.2	11	8
Crotalaria with Ca P	4.9	.16	1.8	6.5	18	14	4.8	.15	1.5	5.8	13	7
Cowpeas	4.9	.17	1.8	6.1	12	9	4.7	.15	1.3	5.0	12	8
Cowpeas with Ca P	5.0	.17	1.8	6.1	13	10	5.0	.15	1.4	5.4	17	9
Soybeans	4.7	.16	1.5	5.4	14	9	4.7	.15	1.5	5.8	13	7
Soybeans with Ca P	5.0	.18	1.8	5.8	16	10	5.0	.16	1.6	5.8	11	9

Treatments	Mayagüez						Mayagüez					
	Mulched and Hoed						Plowed Under					
	pH	N	Org. Matter	C/N	NO_3	P	pH	N	Org. Matter	C/N	NO_3	P
		%	%		p.p.m.	p.p.m.		%	%		p.p.m.	p.p.m.
Check	4.8	.13	1.8	8.0	11	10	4.6	.20	2.5	7.3	8	7
Check with Ca P	5.3	.17	1.8	6.1	8	14	5.4	.19	2.5	7.6	7	9
Velvet beans	4.8	.19	2.0	6.1	13	9	4.5	.21	2.6	7.2	11	7
Velvet beans with Ca P	5.7	.17	1.9	6.5	12	18	5.5	.22	2.7	7.1	7	9
Crotalaria	4.9	.18	1.9	5.8	12	8	4.6	.21	2.6	7.2	10	6
Crotalaria with Ca P	5.3	.18	1.8	5.8	11	15	5.5	.20	2.6	7.5	9	10
Cowpeas	4.7	.18	1.9	6.1	8	8	4.6	.21	2.5	6.9	10	7
Cowpeas with Ca P	5.6	.16	1.9	6.9	12	17	5.6	.20	2.5	7.3	7	9
Soybeans	4.7	.18	1.9	5.8	11	9	4.6	.20	2.6	7.5	7	6
Soybeans with Ca P	5.9	.17	1.8	6.1	11	17	5.6	.20	2.6	7.5	10	9

There was no significant difference found between the organic matter contents of the fields at Mayagüez and Río Piedras due to treatments. This indicates that the incorporation of green manure from velvet beans, crotalaria, cowpeas, and soybeans, respectively, plus the trash from one sweet potato and one corn crop, had no effect upon increasing the organic matter content of the soil, in the presence or absence of lime and phosphorus, after a period of twenty seven months.

SUMMARY

Data are presented here on the effect that four types of green manure had, on the yields of one sweet potatoes and two corn crops planted in two acid soils of Puerto Rico, in the absence or presence of lime and phosphorus. Comparison is also made as to what effect the green manure had on the crop yields when it was applied as a mulch or when it was plowed under the soil. In the last corn crop, the effect of fertilizing with potash was also studied as well as the effect of adding inorganic nitrogen and potash to the check plots, in the absence or presence of lime and phosphorus. The field experiments were established in Fajardo clay at Río Piedras and in Catalina clay level phase at Mayagüez, located about 75 miles apart.

The green manure sources were from four leguminosae: velvet beans *Stizolobium deeringianum;* crotalaria *Crotalaria striata;* cowpeas *Vigna sinensis;* and soybeans *Soja max* Otootan variety. The sweet potato used was the Don Juan variety and the corn was the Mayorbela variety, a flinty type.

In general, the leguminosae and the crops responded significantly to lime and phosphorus. Velvet beans gave the highest significant yields of green manure. In general, the velvet beans with lime and phosphorus gave the highest significant yields of sweet potatoes and corn. Cowpeas showed a highly significant detrimental effect in the yield of sweet potatoes. When the green manure was either mulched or plowed under the soil there was no significant difference between the yields of sweet potatoes and corn.

The last corn crop at Mayagüez responded significantly to the application of potash and to the application of potash and inorganic nitrogen specially when lime and phosphorus were added to the checks, but no response was obtained with the green manures. No response to potash in the check and green manure plots were obtained at Río Piedras.

RESUMEN

Se estudió el efecto de cuatro tipos de abono verde sobre los rendimientos de una cosecha de batatas y dos de maíz sembradas en dos suelos ácidos de Puerto Rico. También se estudió dicho efecto cuando se encaló el suelo y se le aplicó fósforo así como cuando se dejó el abono verde sobre el terreno o se incorporó al suelo con arado. En la última cosecha de maíz también se estudió el efecto de abonar con potasa todos los tratamientos y de abonar con nitrógeno inorgánico y potasa las parcelas testigos, con o sin cal y fósforo. Los experimentos de campo se llevaron a cabo en un suelo Fajardo arcilloso en Río Piedras y en un Catalina arcilloso, fase plana, en Mayagüez, a distancias de 75 millas entre ambas localidades.

Los abonos verdes usados fueron de cuatro leguminosas: habas terciopelo, *Stizolobium deeringianum;* crotalaria *Crotalaria striata;* fréjoles *Vigna sinensis* y habas sojas *Soja max.*

Las leguminosas y las cosechas respondieron significativamente a la cal y el fósforo. Las habas terciopelo dieron el rendimiento más alto de abono verde y cuando se usó cal y fósforo dieron los mejores rendimientos de batatas y maíz. El abono verde de los fréjoles fué detrimental a las batatas.

No hubo diferencia significativa entre los rendimientos de batatas y maíz cuando el abono verde se dejó sobre el suelo o se incorporó con arado.

La última cosecha de maíz en Mayagüez, respondió significativamente a la aplicación de potasa y de nitrógeno inorgánico especialmente cuando se añadió cal y fósforo. No hubo efecto favorable cuando se añadió potasa a los tratamientos de abono verde, en ambos sitios. Tampoco hubo efecto favorable en Río Piedras cuando se añadió potasa y nitrógeno inorgánico, a las parcelas testigos, en la presencia o ausencia de cal y fósforo.

CONCLUSION

Better yields of sweet potatoes and corn are obtained in the acid soils of Puerto Rico when lime, phosphorus, and velvet beans as a green manure source, are added. Soils deficient in nitrogen and potash require also additional fertilization with nitrogen and potash.

Conclusión

Mejores rendimientos de batatas y maíz se obtienen en los suelos ácidos de Puerto Rico cuando se aplica cal, fósforo y abono verde derivado de habas terciopelo. Los suelos que están deficientes en nitrógeno y potasio también deben de abonarse con nitrógeno y potasa.

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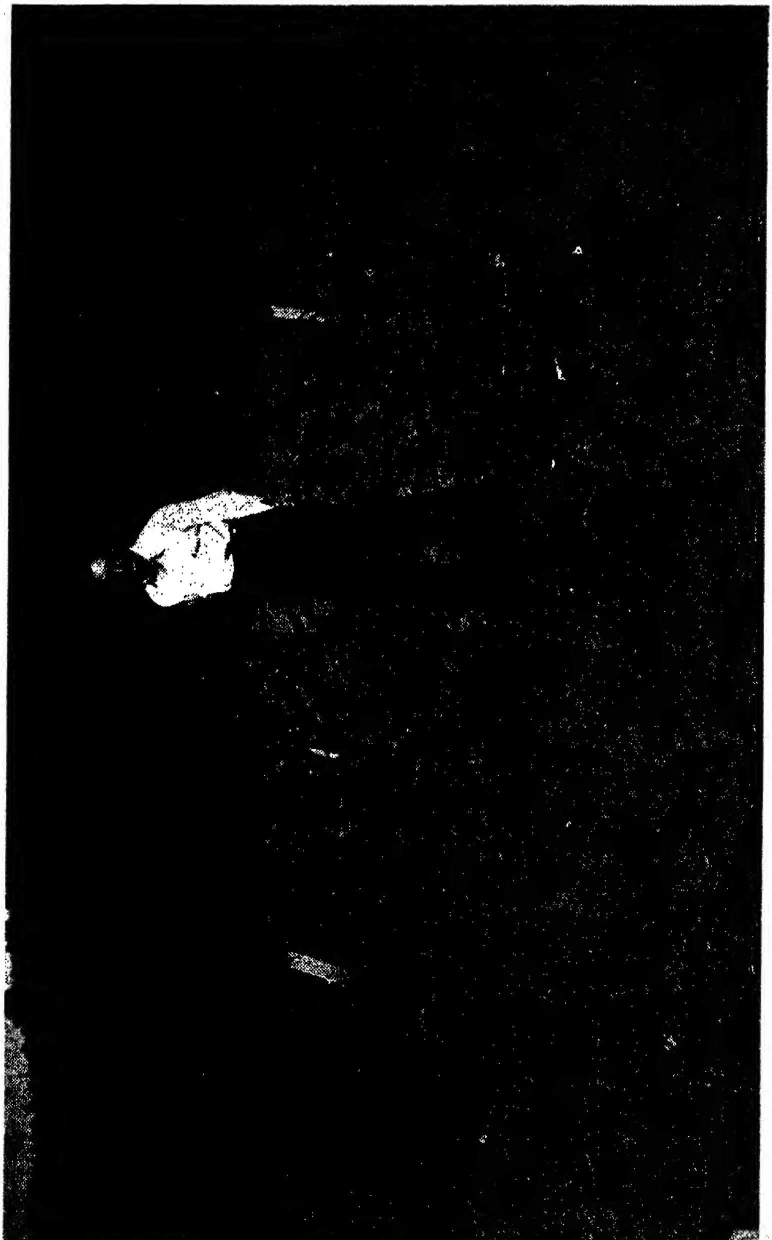

PHOTO 1.—Corn 33 days old, the sixth crop in the rotation grown in Fajardo clay at Río Piedras without lime and phosphorus.

PHOTO 2.—Corn, 33 days old, the sixth crop in the rotation, grown in Fajardo clay at Río Piedras with lime and phosphorus.

PHOTO 3.—Corn 33 days old, the sixth crop in the rotation grown in Fajardo clay at Río Piedras with green manure from velvet beans, lime and phosphorus.

PHOTO 4.—Corn 74 days old, the sixth crop in the rotation, grown in Fajardo clay Río Piedras, with green manure from velvet beans, lime and phosphorus.

PHOTO 5.—Ears of corn harvested at Mayagüez in the sixth crop of the rotation. Counting from right to left:

1.	Check	3.0 bu. per acre
2.	Lime-phosphorus	11.5 bu. per acre
3.	Green manure from velvet beans	10.8 bu. per acre
4.	Green manure from velvet beans with lime and phosphorus	29.3 bu. per acre

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